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FINAL REPORT

PILOT TESTING PROGRAM FOR PROTOCOLS FOR LEAD-BASED PAINT ENCAPSULANTS

Prepared by

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for

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DISCLAIMER

AUTHORS AND CONTRIBUTORS

This study was funded and managed by the U.S. Environmental Protection Agency. The study was conducted by Battelle Memorial Institute under contract to the Environmental Protection Agency. Each organization's responsibilities are listed below.

Battelle Memorial Institute (Battelle)

Battelle was responsible for designing and conducting the study, selecting and managing the subcontracted testing laboratories (Center for Applied Engineering and Professional Service Industries), performing statistical analyses on the study data, developing the conclusions and recommendations derived from the analyses, and writing the final report.

U.S. Environmental Protection Agency (EPA)

The Environmental Protection Agency was responsible for managing the study, providing guidance on the objectives for the study and report, contributing to the development of conclusions and recommendations, and coordinating the EPA and peer reviews of the draft report. The EPA Work Assignment Managers were Jill Hacker and Barbara Leczynski. The EPA Project Officer was Jill Hacker.

Executive Summary

A significant source of lead in many childhood environments is old deteriorating leaded paint. Exposure to lead by children under the age of seven can cause serious health problems, including irreversible central nervous system damage resulting in learning and behavioral disabilities. Many older housing structures in the U.S. have been found to contain substantial amounts of leaded paint, some of which is in poor condition. Therefore, several measures, including the use of encapsulants, are being investigated as methods to help control exposures to lead-based paint hazards.

Encapsulants are durable coatings systems designed to cover existing leaded paint, and thereby control the further deterioration of the paint and the resulting distribution of fine lead particles to household dust and exterior soil. However, most encapsulant products are relatively new and there is currently little information that can be used to predict their effectiveness. Furthermore, approved performance standards do not yet exist which can be used to approve these products for use in residential environments. The American Society for Testing and Materials (ASTM) Task Group E06.23.30 on Encapsulation of Leaded Paint is currently developing such standards; however, few data have been submitted to ASTM which can serve as the technical basis for setting these standards.

Recognizing this critical need for data, the U.S. Department of Housing and Urban Development (HUD) and the U.S. Environmental Protection Agency (EPA) decided to begin evaluating currently available tests for encapsulation products. The performance properties and test methods identified to date by ASTM E06.23.30 have wide use in testing paint products and specialty coatings. However, only limited testing with these protocols has been performed on encapsulant products, and the viability of many test

methods for use with encapsulants is not yet known. Therefore, the overall objective of this study was to evaluate the appropriateness of standard ASTM test protocols for assessing the performance characteristics of encapsulants for leaded paint. Specifically, the study was intended to (1) collect data to help determine the feasibility of a battery of test protocols drafted by ASTM E06.23.30 using both liquid coatings and reinforced liquid coatings; (2) provide information that can support the assessment of existing draft minimum performance standards; and (3) assess the variability of these test methods between two laboratories and within a single laboratory. The results of this study have been analyzed at two levels, a qualitative evaluation of the feasibility of conducting the tests on these new encapsulant products, as well as a quantitative statistical analysis to assess variability in the test data.

This report presents the results from these testing activities. Testing was conducted in April-August of 1994 at two independent laboratories, and included a set of ten standard ASTM protocols run under ambient laboratory conditions, as well as after water immersion or weathering. Tests were run on 6 liquid encapsulants, 4 reinforced encapsulants, and 4 paints. These products were generally applied to various standard metal or plastic test panels before testing according to the ASTM protocols although one set of tests involved evaluating free films of each coating. This study generated approximately 3800 new data on the performance of encapsulation products.

It is important to note several caveats associated with this study which limit the extent to which the results and conclusions can be projected to other laboratories and coating products. First, it must be emphasized that this project was intended to evaluate the ASTM test protocols and not to evaluate the selected coating products. While comparisons among various products are made in this report, these analyses are only used to better understand the variability which might be expected in the results from the test protocols. Second, only two laboratories participated in the testing of this project, and these laboratories were not chosen at random from the hundreds of U.S. facilities that could have performed the tests. The two participating laboratories were chosen, based on technical and cost factors, from among approximately ten firms which responded to a competitive request for proposals. Finally, only a limited number of coating products were tested in this project, and these products were not chosen at random, but instead were selected specifically to represent the range of products available in 1994. Because neither the products nor the laboratories were chosen at random, it is not possible to extend the results from this study to the broader population of products and laboratories available in the U.S.

The overall study conclusions can be summarized according to each of the three project objectives stated above. First, the feasibility of testing was evaluated for 13 ASTM protocols or combinations of protocols, and in almost all cases the selected protocols were found to be feasible. The two notable exceptions where serious procedural difficulties were encountered were the pull adhesion test run after water immersion and the scrub resistance test run after weathering. Other difficulties were also experienced for some particular combinations of test protocols and encapsulant products. Second, assessment of the 1995 draft ASTM minimum performance standards found five tests where draft standards were available. In all cases the draft standards were found to be feasible because they fell within the range of all observed test results. Third, evaluation of testing variability between two laboratories and within a single laboratory focused on both product-to-product and panel-to-panel differences. As might be expected, the variability in test results was quite different depending on the particular protocol and products being tested. In some cases no variability was found (i.e., all test results were the same), while in other cases the standard deviation of the test data was more than 100% of the mean value measured.

The qualitative assessment of the test methods examined practical problems associated with conducting the protocols on encapsulant products, as well as issues that could affect the ability of the methods to distinguish among different types of products based on test performance. Overall, most of the test protocols were found to be feasible for most of the encapsulants selected, although there were testing challenges in some cases. The major issues identified by the qualitative evaluation for each method are as follows:

- Tape adhesion -- This is a semi-quantitative test with limited sensitivity (i.e., ability to distinguish among products) that rates coatings on a scale from 0 to 5. This test was not performed for reinforced products because cutting the product, which is a necessary step in the method, is likely to introduce stresses to the coating which can adversely affect adhesion.

- Pull adhesion -- Instrumentation is an important factor for this test and should be selected to meet the anticipated pull-off strengths of the coatings to be tested. The dolly adhesive is also quite important because several cases were observed where the adhesive failed to adhere well either to the dolly itself, or to the product being tested. This issue was particularly important when testing after water immersion since fastening the dolly soon after immersion was not feasible because the dolly adhesive would not cure to the wet surface, and fastening the dolly before immersion did not allow for complete exposure of the product to the water. Also, scoring around the dolly is an option under ASTM D 4541 so that this test measures local adhesion rather than adhesion distributed across the entire panel. However, scoring is difficult with reinforced products and may stress the coating causing loss of adhesion. In addition, the 0.01 inch tin-plated steel panel used in this study was found to be too thin because it deformed during execution of the test. This protocol is no longer included by ASTM E06.23.30 for adhesion testing.

- **Scrub resistance** -- Because of the wide range of coating thicknesses tested it was difficult to distinguish among various products. This test is designed to be run until failure, although ASTM E06.23.30 currently only requires testing to 1200 cycles. However, many products were tested to 5000 cycles without failure which was quite labor intensive and time consuming. In fact, all reinforced encapsulants tested were run to 5000 cycles without failure, indicating that this test may be inappropriate for such products. In addition, scrub testing after weathering caused two technical problems. First, the standard plastic panels were too large to fit in the weathering chamber. The panels had to be cut to fit the chamber necessitating modification of the sample holding frame on the scrub test machine. Second, the black plastic panels warped and deformed in the weathering cycle so that the test surface was not flat.

- **Flexibility** -- This test could not be run on one product because the test panels were too thick to fit into the testing apparatus. Also, questionable results were obtained for products with poor adhesion to the tin-plated steel panels used for testing.

- **Impact resistance** -- In the case of the cementitious products, it was difficult to determine whether cracking or simply compression of the coating occurred after impact, thereby making the impact resistance measurements uncertain.

- **Dry abrasion resistance** -- Because this test records both cycles to failure and weight loss, it provides two quantitative measures of product durability. However, testing of the cementitious products was problematic due to excessive wear of the abrasion wheels.

- **Viscoelastic properties** -- Difficulties were encountered producing free films for some products. In the case of many reinforced products, it was also difficult to cut the coatings into strips for testing without stressing the samples and causing a loss of tensile strength. Tensile strength was found to be greatly affected by the reinforcing material although no quantitative assessment of the effect of the reinforcing mats was made. In addition, there were several cases where stiffness of the films could not be measured because the samples ruptured before 1% elongation was reached, which is the point at which the first measurement is taken.

- **Blistering, chalking, and pencil hardness -- No serious problems were encountered, although these are semi-quantitative tests with only limited sensitivity to detect differences among products.**

The quantitative assessment of the test methods addressed four different objectives: (1) compare test results against draft ASTM E06.23.30 standards, (2) assess differences between two testing laboratories, (3) assess within-laboratory differences among replicate test panels and replicate encapsulant samples, and (4) assess the ability of different test methods to distinguish among different types of products. The following points summarize some of the most important findings from the statistical analysis:

- **ASTM E06.23.30 draft standards were available for five of the tests performed in this study -- tape adhesion, scrub resistance, flexibility, impact resistance, and chalking. In all cases the draft standards appeared reasonable from the perspective that many of the products would have passed, and thus the standards do not appear to be too restrictive. However, not all products would necessarily have passed the standards, and thus the standards also do not appear to be too loose.**

- **Laboratory differences were found to be large for tape adhesion for unexposed panels and panels after water immersion, scrub resistance for unexposed panels, and impact resistance.**

- **Measurement variability among replicate test panels was found to be significant for pull adhesion for unexposed panels and viscoelastic elongation. Replicate product variability was found to be significant for tape adhesion for unexposed panels (products LE3 and LE5) and viscoelastic elongation. In all cases, greater variability in the test data leads to a requirement for a greater number of tests to demonstrate statistical significance in the results, for example, to demonstrate differences among various products.**

- **The data in some cases indicated different readings for unexposed panels and exposed panels--tape adhesion performed after water immersion and weathering, pull**

adhesion performed after water immersion and weathering, scrub resistance performance after weathering, and pencil hardness performed after water immersion (greater differences for liquid products than for reinforced products). The data in two cases indicated no differences between the test results for exposed and unexposed panels--flexibility and blistering.

- **Results for several tests were found to be different for liquid products and reinforced products--pull adhesion after weathering, scrub resistance, dry abrasion, viscoelastic properties, blistering, and pencil hardness. Results in five cases were found to be essentially the same for liquid and reinforced products--tape adhesion, pull adhesion for unexposed panels, flexibility, impact resistance, and chalking.**

- **Testing results in several cases indicated significantly different readings for the liquid encapsulants and paints--tape adhesion, pull adhesion, scrub resistance, impact resistance, dry abrasion, and viscoelastic properties. Testing results in four cases indicated no significant difference between readings for liquid encapsulants and paints--flexibility, blistering, chalking, and pencil hardness.**

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1.0 INTRODUCTION

Childhood lead poisoning has been recognized as one of this country's most important environmental health problems. Exposure of children under the age of seven to significant amounts of lead can cause a variety of health problems, perhaps the most common and notable of which is irreversible central nervous system damage resulting in learning and behavioral disabilities. As a result, Congress has enacted a broad program of regulatory, policy, educational, and research initiatives aimed at eliminating childhood lead poisoning.

One significant source of lead in many childhood environments is old deteriorating leaded paint. Lead was a common constituent of paint up until 1978 when it was essentially banned for residential use by the Consumer Product Safety Commission. Many older housing structures, particularly many built before 1970, may contain significant amounts of leaded paint, some of which may be in poor condition. When this paint deteriorates, it distributes fine particles of lead which contaminate household dust and exterior soil. This dust and soil can then be accidentally ingested by young children through their normal hand-to-mouth and play activities.

As a result of these concerns with leaded paint in housing, the federal government is investigating the feasibility of using encapsulation as a means to help protect the environment from deteriorating leaded paint. However, because many of these products are so new, there is currently little information that can be used to reliably predict their effectiveness. The goal of this study is to collect information to help assess what laboratory protocols are appropriate for testing product performance.

The American Society for Testing and Materials (ASTM) Task Group E06.23.30 on Encapsulation of Leaded Paint is developing a set of performance specifications for encapsulants for leaded paint. These standards, which are being drafted for both liquid coatings and reinforced liquid coatings, will list required performance properties, identify ASTM methods to test the products under standard laboratory conditions, and set minimum performance criteria which products must meet to be classified as approved encapsulants for leaded paint. The performance properties and test methods identified to date by the ASTM Task

Group have wide use in testing paint products and specialty coatings. However, only limited testing with these protocols has been performed on encapsulant products and few data from these tests have been submitted to ASTM. Therefore, serious questions have been raised about the appropriateness of these performance tests. Without supporting test data, it will be impossible to successfully ballot the ASTM standards and release these protocols to the general public. Because a critical need for these standards exists in the lead abatement industry, performance data must be collected in a timely fashion.

Recognizing this critical need for data, the U.S. Department of Housing and Urban Development (HUD) and U.S. Environmental Protection Agency (EPA) decided to begin evaluating currently available tests for encapsulation products. This report presents results from a study to evaluate the ASTM test protocols by collecting laboratory data on a selected set of encapsulation products for some of the performance properties and test methods selected by the ASTM Task Group. For comparison purposes, the study also included testing of a set of paint products. A representative set of encapsulants and paints was tested to ensure that data on a broad range of coatings were collected. The actual products selected for the study will not be discussed in this report since product selection does not imply product endorsement.

Testing was conducted at two independent laboratories selected through a competitive procurement process. Testing at two laboratories provided information on the variability of the test results. The resulting data will be used to help judge the feasibility and appropriateness of the proposed ASTM methods and to help set minimum performance criteria for encapsulation products.

It is important to recognize two constraints on this study. First, the study was intended to evaluate potential encapsulant testing protocols, rather than to evaluate the performance of currently available encapsulants. Test data currently exist only for paints and coatings. Therefore, this program provides new data where the standard test protocols are applied to new coatings and materials representing encapsulant products. Second, because this study performed testing on materials which may never have been tested before, it was possible that some of the standard ASTM protocols would not work as planned in some situations. For example, standard testing for viscoelastic properties requires the laboratory to produce a free film of the coating being tested. This was extremely difficult with some of the new encapsulant materials. In cases where the tests could not be completed as planned, the resulting study data consist of detailed comments on the test results rather than numerical measurements or objective qualitative rankings. Because of these study constraints, this project must be viewed as a pilot testing program.

1.1 PEER REVIEW

The technical report on this study was reviewed independently by members of a peer review panel. With the exception of the one comment discussed below, all of the comments received were either informational and required no changes, or were editorial in nature.

One comment was made concerning the reviewer's interpretation that the data indicates that the samples were not fully cured prior to being tested, thereby causing a question regarding the validity of the entire test program. The report was clarified to point out that, with the exception of three products which were tested too early by one laboratory for impact resistance, all tests in the study were performed on all panels after the manufacturers' recommended cure times. It is also important to note that the impact resistance results for the three affected products were among the highest for any products tested. Based on these facts, the validity of the entire test program was not jeopardized by premature testing of any samples.

EPA has established a public record for the peer review under administrative record AR144. The record is available in the TSCA Nonconfidential Information Center, which is open from noon to 4 PM Monday through Friday, except legal holidays. The

TSCA Nonconfidential Information Center is located in Room NE-B607, Northeast Mall, 401 M Street SW, Washington, D.C.

2.0 STUDY DESIGN

This testing program collected more than 1000 individual test results from each of two testing laboratories. Tests were run on 18 coatings, including 12 liquid coatings and 6 reinforced coatings. The tests included a variety of standard ASTM protocols run under ambient laboratory conditions, as well as on samples which were subjected to water immersion and weathering conditions. This section describes the design of the encapsulant pilot testing program, including the study objectives, ASTM testing methods, and selection of products for testing. The design is more fully described in the Quality Assurance Project Plan that was developed by EPA (1).

2.1 STUDY OBJECTIVES

The overall objective of this study was to evaluate the appropriateness of some of the ASTM E06.23.30 test protocols for assessing the performance characteristics of encapsulant products for leaded paint. It should be noted that these tests for coatings do not directly evaluate the ability of encapsulants to contain an existing leaded paint hazard. For example, the tests do not assess the potential leaching of lead from an underlying paint through an encapsulant. Instead, these tests evaluate physical characteristics such as adhesion of the coatings which are properties that an encapsulant must also have if it is to successfully contain a leaded paint hazard. Therefore, the term "appropriate," as used in this study, refers to the ability of existing test methods to reliably measure such physical properties of encapsulants.

Specifically, this study was intended to satisfy the following objectives:

- Collect laboratory data to help determine the feasibility of some test protocols drafted by ASTM Task

Group E06.23.30 on encapsulation of leaded paint using both liquid coatings and reinforced liquid coatings.

- **Compare the collected laboratory data with current ASTM E06.23.30 minimum performance standards to help assess which standards are appropriate.**
- **Assess the variability of these test methods, both between two laboratories and within a single laboratory.**

Note that these objectives reflect the pilot nature of this testing program. As noted earlier, there is little, if any, documented experience with these ASTM methods for many of the encapsulant products. Therefore, while the need of EPA, HUD, and ASTM is to select final test protocols and set minimum performance standards for encapsulant products, this program will not be able to make firm recommendations on these selections. Instead, this program has generated a wealth of new data to perhaps rule out some protocols which are inappropriate for some encapsulant products and rule in other protocols which do appear appropriate. In addition, comparison of these study data with current ASTM E06.23.30 standards will help determine the levels at which minimum performance standards should be set.

Because this is a pilot study, the data quality objective (DQO) was stated in terms of data completeness and traceability, rather than in terms of a formal hypothesis test or statistical estimation objective. Specifically, the DQO for this study was as follows:

> **Obtain 95% data completeness for a battery of ASTM test protocols run on multiple encapsulant products at two different testing laboratories.**

Actual data completeness includes not only the quantitative measurements and qualitative rankings expected from each test,

but also detailed comments on why a particular test could not be completed as planned in those cases where the test was found to be inappropriate for a particular encapsulant.

2.2 SELECTION OF ASTM TEST METHODS

This study was primarily a data collection program to generate new information on which test protocols may, or just as importantly may not, be suitable for encapsulant testing. The products were selected to represent a broad range of coatings including paints, liquid encapsulants, and reinforced liquid encapsulants. The tests evaluated were those for physical properties, as opposed to chemical properties, and included dry film thickness, scrub resistance, impact resistance, flexibility, dry abrasion resistance, adhesion, viscoelasticity, water immersion, weathering, blistering, pencil hardness, and chalking.

When this study was initiated in October, 1993 the ASTM Task Group E06.23.30 had drafted an initial set of test protocols for assessing the performance of encapsulant products. While the budget for this pilot testing program did not allow evaluation of all the physical test protocols, the vast majority were included. Also, in the months since this study was initiated ASTM has revised some of its performance tests and standards. Therefore, while most of the tests performed in this study were the same as those currently stipulated by ASTM, all of the test protocols used in this study were not identical to the ASTM protocols. Specifically, the scope of this study included a set of 20 tests, most of which were specified by ASTM E06.23.30, although some were run here for longer times or in slightly different conditions than those selected by the task group. As shown in Tables 1 and 2, 13 of these tests were run on products intended for interior residential use, and all 20 tests were run on products intended for exterior residential use. While Tables 1

and 2 contain short titles and ASTM designations for these tests, Table 3 lists more detailed ASTM designations.

A brief description for each of the tests is listed below.

- **<u>Dry Film Thickness (D 1186)</u> - The thickness of the dried encapsulant on a ferrous panel was measured using an instrument that is based on magnetic measuring principles.**

Table 1. Summary of Performance Tests on Encapsulants for Interior Use

Performance Property	ASTM Test Method	Liquid Products	Reinforced Products	Panels Per Product
Dry Film Thickness	D 1186 D 1005	Yes	Yes	All
Tape Adhesion	D 3359	Yes	No	1
Pull Adhesion	D 4541	Yes	Yes	3
Scrub Resistance	D 2486	Yes	Yes	3
Flexibility	D 522	Yes	Yes	3
Impact Resistance	D 2794	Yes	Yes	4
Dry Abrasion Resistance	D 4060	Yes	Yes	2
Viscoelastic Properties	D 2370	Yes	Yes	10
Water Immersion	D 1308	Yes	Yes	4 liquid 3 reinforced
Post-Immersion Tape Adhesion	D 3359	Yes	No	1
Post-Immersion Pull Adhesion	D 4541	Yes	Yes	3
Post-Immersion Blistering	D 714	Yes	Yes	All 3 or 4
Post-Immersion Pencil Hardness	D 3363	Yes	Yes	All 3 or 4

Table 2. Summary of Performance Tests on Encapsulants for Exterior Use

Performance Property	ASTM Test Method	Liquid Products	Reinforced Products	Panels Per Product
Dry Film Thickness	D 1186 D 1005	Yes	Yes	All
Tape Adhesion	D 3359	Yes	No	1
Pull Adhesion	D 4541	Yes	Yes	3
Scrub Resistance	D 2486	Yes	Yes	3
Flexibility	D 522	Yes	Yes	3
Impact Resistance	D 2794	Yes	Yes	4
Dry Abrasion Resistance	D 4060	Yes	Yes	2
Viscoelastic Properties	D 2370	Yes	Yes	10
Water Immersion	D 1308	Yes	Yes	4 liquid 3 reinforced
Post-Immersion Tape Adhesion	D 3359	Yes	No	1
Post-Immersion Pull Adhesion	D 4541	Yes	Yes	3
Post-Immersion Blistering	D 714	Yes	Yes	All 3 or 4
Post-Immersion Pencil Hardness	D 3363	Yes	Yes	All 3 or 4
Weathering	G 53	Yes	Yes	10 liquid 9 reinforced
Post-Weathering Tape Adhesion	D 3359	Yes	No	1
Post-Weathering Pull Adhesion	D 4541	Yes	Yes	3
Post-Weathering Scrub Resistance	D 2486	Yes	Yes	3
Post-Weathering Flexibility	D 522	Yes	Yes	3
Post-Weathering Blistering	D 714	Yes	Yes	All 9 or 10
Post-Weathering Chalking	D 4214	Yes	Yes	All 9 or 10

Table 3. Referenced Documents[a]

ASTM Designation	Title
D 16-91	Standard Terminology Relating to Paint, Varnish, Lacquer, and Related Products
D 522-92	Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings
D 609-90	Standard Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products
D 714-87	Standard Test Method for Evaluating Degree of Blistering of Paints
D 823-92a	Standard Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels
D 1005-84 (Reapproved 1990)	Standard Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers
D 1186-87	Standard Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base
D 1308-87	Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
D 2370-92	Standard Test Method for Tensile Properties of Organic Coatings
D 2486-89	Standard Test Method for Scrub Resistance of Interior Latex Flat Wall Paints
D 2794-92	Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
D 3359-92a	Standard Test Methods for Measuring Adhesion by Tape Test
D 3363-92a	Standard Test Method for Film Hardness by Pencil Test
D 4060-90	Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
D 4214-89	Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
D 4541-85 (Reapproved 1989)	Standard Test Methods for Pull-Off Strength of Coatings Using Portable Adhesion Testers
D 4708-92a	Standard Practice for Preparation of Uniform Free Films of Organic Coatings
G 53-91	Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials

(a) 1993 Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, Pennsylvania.

- Dry Film Thickness (D 1005) - The thickness of the dried encapsulant on a panel, or as a free film, was measured using a hand-held or stationary micrometer.

- Tape Adhesion (D 3359) - The adhesion of the encapsulant to a substrate was evaluated by applying pressure-sensitive tape over an X-cut in the film of a coated panel and removing the tape. The amount of film torn from the panel was qualitatively assessed according to the test protocol.

- Adhesion-Pull (D 4541) - The adhesion of the encapsulant to a substrate was evaluated by securing a button (dolly) to the surface of the coating and measuring the force required by the testing apparatus to detach the button from the panel.

- Scrub Resistance (D 2486) - The resistance of the encapsulant to erosion caused by scrubbing was determined by securing a coated black plastic panel over a shim in a washability machine and scrubbing with a nylon bristle brush and abrasive medium until failure occurred.

- Flexibility (D 522) - The resistance of the encapsulant to cracking was determined by bending a coated metal panel over a conical mandrel. The distance from the end of the longest crack to the small end of the mandrel was used to compute elongation.

- Impact Resistance (D 2794) - The resistance of the encapsulant to cracking caused by direct impact was measured by repeatedly dropping a standard weight onto the coated surface of a sample panel, increasing the height the weight dropped, until failure occurred.

- Dry Abrasion Resistance (D 4060) - The abrasion resistance of the encapsulant was measured by rotating a coated metal panel under weighted abrasive wheels. The loss in weight after a specified number of abrasion cycles or the cycles to failure was reported.

- Viscoelastic Properties (D 2370) - The elongation, tensile strength, and stiffness of the encapsulant as a free film were measured by means of a tensile testing apparatus that elongated the film until it ruptured.

- Water Immersion (D 1308) - Coated panels were immersed in water for 24 hours and then checked for degradation effects such as blistering, loss of adhesion, and softening. ASTM tests for blistering, pencil hardness, and adhesion were conducted on the panels that were immersed.

- Weathering (G 53) - Coated panels were alternately exposed to ultraviolet light and then to condensation in a repetitive cycle for a fixed period of time and then checked for visible degradation effects. ASTM tests for blistering, chalking, adhesion, flexibility, and scrub resistance were conducted on the panels that were weathered.

- Blistering (D 714) - The degree of blistering that the encapsulant developed after weathering or water immersion was evaluated by qualitatively comparing the subjected coated panels to photographic reference standards.

- Chalking (D 4214) - The degree of chalking that the encapsulant developed after weathering was measured by qualitatively comparing a piece of fabric that had been rubbed with medium pressure against the coated panel to photographic reference standards.

- Pencil Hardness (D 3363) - The film hardness of the encapsulant was determined by pushing pencil leads with various degrees of hardness against the coated panel and determining the hardest pencil lead that would not gouge the film.

In all cases, the study design included a basic set of eight performance tests run on unexposed panels (i.e., not immersed in water and not weathered) to evaluate dry film thickness, scrub resistance, impact resistance, flexibility, dry abrasion, adhesion, and viscoelastic properties. Adhesion was evaluated for all products with a pull-off strength test (ASTM D 4541); and in addition, for liquid products (i.e., those without a fabric, mat, or mesh reinforcement) adhesion was evaluated with a tape test (ASTM D 3359). The study design for all products also included a basic set of five tests to evaluate blistering, pencil hardness, and adhesion after 24 hours of immersion in distilled water at 23° ± 2° C (73.4° ± 3.6° F). Panels were tested 10-20 minutes and/or 2 hours after withdrawal from the water, depending on the test. Once again, adhesion after water immersion was evaluated for all products with the pull-off strength test, and in addition for liquid products with the tape test.

The major difference between the tests for interior products listed in Table 1 and the tests for exterior products listed in Table 2 was that a set of seven tests after weathering was included in Table 2 for exterior products. This additional set of tests evaluated blistering, chalking, adhesion, flexibility, and scrub resistance after 1000 hours of alternating fluorescent ultraviolet radiation in wavelengths between 315 nm and 400 nm (UV-A) and condensation exposure. In this case the weathering cycle was used to simulate deterioration caused by sunlight and water. Sample panels (3 inches by 6 inches) were cycled in a test chamber (as specified by ASTM G 53) for 1000 hours. ASTM G 53 describes the test apparatus in detail. The two major U.S. suppliers of these test chambers are Q-Panel Co., Cleveland, Ohio and Atlas Electric Services Company, Chicago, Illinois. The weathering cycle consisted of UV-A exposure at 340 nm peak emission for four hours at 60°C, alternating with condensation for four hours at 50°C. Panels were observed for visible changes at 500 hours.

2.3 SELECTION OF ENCAPSULANT PRODUCTS

A representative set of 10 encapsulant products was chosen for the test protocol evaluation. To determine this set of products, an assessment was made of the range of encapsulant product types currently available, and then different products representing various use categories and various chemical and physical formulations were selected for testing. In this way a wide range of product types was presented to the ASTM protocols to help determine where the test methods can provide reliable performance data.

The first step in selection of a representative group of liquid and reinforced encapsulant products for the current study was to identify products commercially available in the U.S architectural paint market. The products of interest in this study were designed for encapsulating old leaded paint on interior or exterior surfaces in residential units. A list of available encapsulant products for leaded paint was compiled from materials provided by HUD and EPA, and from product listings and advertisements in trade journals such as the *Journal of Protective Coatings and Linings, Modern Paints and Coatings*, and the *Journal of Coating Technology*. Additional products were identified by direct contact with vendors and representatives of the Steel Structures Painting Council at the 1993 Federation of Societies for Coatings Technologies Annual Meeting and Paint Industries Show. Current commercial status of products from all these sources was verified by direct contact with the suppliers. As shown in Table 4, a group was assembled of 36 commercial encapsulant products which were supplied by 23 companies for use as architectural coatings. This group includes most of the products used for encapsulation of residential leaded paint which were available in the U.S. in December, 1993 and is as complete a listing as time and cost constraints of the current study allowed.

The identified products were categorized as liquid or reinforced coatings. For this study reinforced products were defined as those that incorporate a fabric, mat (woven or non-woven), or mesh reinforcement with a polymeric or cementitious coating. According to the manufacturer, a number of the identified products could be applied with or without the reinforcement. Therefore, when categorizing products in Table 4, some products were essentially classified twice, once with a reinforcing material, and once without. The liquid and reinforced groups were further characterized in Table 4 by primary use category because the ASTM protocols are different for interior and exterior products. Some products can be used both for interior or exterior applications, as noted in the table.

Table 4 also shows the wide range of product types currently available. A variety of polymers and polymer combinations were identified, and the reinforcing materials varied in chemical composition and weave. Acrylic polymers were the most common in residential encapsulants. However, epoxy, cementitious, hybrid (combinations of polymers), and other (considered proprietary) types of coatings were also found. The physical properties of the commercial encapsulant products varied between and within generic types; for example, there were both flexible and rigid products represented.

Table 4. Summary of Encapsulant Products Identified

		Generic Product Type					
Use Category		Acrylic	Epoxy	Hybrid*	Cementitious	Other**	Total
	Interior	2	1	--	1	--	4
	Exterior	1	1	--	1	1	4
	Interior/ Exterior	8	--	3	--	1	12
	Total	11	2	3	2	2	20
	Interior	1	1	1	1	3	7
	Exterior	--	--	--	1	--	1
	Interior/ Exterior	4	--	1	2	1	8
	Total	5	1	2	4	4	16

* Combination of polymers
**Proprietary polymer

Products were selected for testing in this study to represent the variety of use categories and product types currently available. The reinforced products were selected as much as possible to include a variety of reinforcement types. However, the small number of reinforced products scheduled for testing in this program placed limits on the selection process. As shown in Table 5, 10 encapsulant products were selected, including six liquid products and four reinforced products. The reinforcing materials included polyester woven, polyester non-woven, fiberglass woven, and fiberglass non-woven mats. The structure and composition of the reinforcing mat could affect performance. However, it was not possible in this study to draw conclusions about the effects of mat type on performance based on this limited sample, because each of the reinforced product systems differed from the others in both mat type and binder type. Within the liquid and reinforced categories, the selected encapsulants were evenly split between interior and exterior products, and all generic types were represented. Products designated "interior" for testing were randomly selected from a group of products specified by the manufacturers as "interior use only" or "interior/exterior use." Products designated "exterior" for testing were randomly selected from a group of products specified by the manufacturers as "exterior use only" or "interior/exterior use." A number of products were represented in both the interior and exterior selection pools. Interior products were selected first. If an "interior/exterior use" product was selected for testing as an "interior" product, it was eliminated from the pool of products that could be selected as "exterior." That way, no product could be selected for testing in this program by both interior and exterior protocols.

As shown in Table 5, paint products and replicate encapsulant products were also included in the study design to help assess the accuracy and precision of the ASTM test methods. Commercial paints were selected to represent high quality and low quality interior and exterior paints available on the retail market. One commercial paint manufacturer was drawn at random from a group of five major paint manufacturers available nationwide. All paints were purchased through a retail outlet for this one selected manufacturer. In addition, within each combination of general coating type (i.e., liquid versus

Table 5. Encapsulants and Paints Selected for Testing

Use Category		Number of Products	Generic Product Type
	Interior Encapsulants	3	1 acrylic 1 hybrid* 1 other**
	Exterior Encapsulants	3	2 acrylics 1 hybrid*
	Interior Paints	2	1 acrylic 1 vinyl
	Exterior Paints	2	1 acrylic 1 vinyl
	Replicate Encapsulants	2	1 interior type 1 exterior type
	Total	12	
	Interior Encapsulants	2	1 epoxy (polyester non-woven mat) 1 acrylic (polyester woven mat)
	Exterior Encapsulants	2	1 cementitious (fiberglass woven mat) 1 other** (fiberglass non-woven mat)
	Replicate Encapsulants	2	1 interior type 1 exterior type
	Total	6	

* Combination of polymers
**Proprietary polymer

reinforced) and general use category (i.e., interior versus exterior), one product was randomly selected for replicate testing. That is, two separate samples of each such replicate product were sent to the laboratories as if they were entirely different products. In this way the reproducibility of results within each laboratory could be assessed.

All product samples were purchased in regular commercial containers as supplied by the manufacturers. To prevent a manufacturer from knowing that a purchase within the time frame of this study meant that its product was being tested, product samples, technical literature, and Material Data Safety Sheets (MSDSs) were acquired for more than the 10 products actually selected for laboratory analysis. In this way the products actually tested are not distinguishable to outside observers from products that were purchased but never tested. The four commercial paints were purchased directly from a local retail outlet of a single major producer of architectural paints. The selection of high and low quality paints was made on the manufacturer's own designation of product line and corresponded directly to retail price. Acrylic latex paints were selected as high quality paints because they are the most common type of high-quality architectural paint used on residential units in the U.S. at this time. The low-quality interior paints were vinyl latex, representing the bottom of the manufacturer's line. The 10 selected encapsulant products and four paints were cleared of commercial identifying marks and labeled with three-character Product ID Codes before shipment to the testing laboratories along with the application instructions and product MSDSs. As shown in Table 6, these codes correspond to each of the 18 specific products selected for testing.

Replicate products were purchased in separate containers and shipped with separate product ID codes to the testing laboratories. Product for replicates RN1 and RN2 arrived in a 5-gallon container. Empty regular 1-gallon containers were requested from the manufacturer and the 5-gallon container was mixed and poured into five 1-gallon containers before shipment to the laboratories.

2.4 TEST PLAN

The test plan for this study is summarized in Table 7, which lists the number of tests run at each of the two testing laboratories. The rationale for the design was as follows:

Table 6. Product ID Codes for Encapsulants and Paints Selected for Testing

Category	Product ID Code	Polymer and Reinforcement Type
Liquid Exterior	LE1	Hybrid copolymer latex (acrylic ester, vinyl, urethane)
	LE2 (or HPE)	Acrylic latex (high-quality paint)
	LE3	Acrylic latex (replicate product)
	LE4	Acrylic
	LE5	Acrylic latex (replicate product)
	LE6 (or LPE)	Vinyl latex (low-quality paint)
Liquid Interior	LN1	Other
	LN2 (or HPI)	Acrylic latex (high-quality paint)
	LN3	Waterborne acrylic with primer (replicate product)
	LN4 (or LPI)	Vinyl latex (low-quality paint)
	LN5	Waterborne acrylic with primer (replicate product)
	LN6	Hybrid
Reinforced Exterior	RE1	Cementitious (fiberglass woven mat)
	RE2	Acrylic and polyester composite (fiberglass non-woven mat--replicate product)
	RE3	Acrylic and polyester composite (fiberglass non-woven mat--replicate product)
Reinforced Interior	RN1	Acrylic (polyester woven mat--replicate product)
	RN2	Acrylic (polyester woven mat--replicate product)
	RN3	Epoxy (polyester non-woven mat)

Table 7. Summary of the Number of Performance Tests Run

	Liquid Coatings		Reinforced Coatings	
	Interior	Exterior	Interior	Exterior
Number of Products	6	6	3	3
Number of Tests Per Product: Dry Film Thickness	All 26 panels	All 26 panels	All 25 panels	All 25 panels
Adhesion-Tape	3 locations on 1 panel	3 locations on 1 panel	--	--
Adhesion-Pull	3 panels	3 panels	3 panels	3 panels
Scrub Resistance	3 panels	3 panels	3 panels	3 panels
Flexibility	3 panels	3 panels	3 panels	3 panels
Impact Resistance	4 panels	4 panels	4 panels	4 panels
Dry Abrasion	2 panels	2 panels	2 panels	2 panels
Viscoelastic Properties	10 films	10 films	10 films	10 films
Water Immersion	Total 4 panels	Total 4 panels	Total 3 panels	Total 3 panels
Post-Immersion Adhesion-Tape	3 locations on 1 panel	3 locations on 1 panel	--	--
Post-Immersion Adhesion-Pull	Other 3 panels	Other 3 panels	All 3 panels	All 3 panels
Post-Immersion Blistering	All 4 panels	All 4 panels	All 3 panels	All 3 panels
Post-Immersion Pencil Hardness	2 locations on all 4 panels	2 locations on all 4 panels	2 locations on all 3 panels	2 locations on all 3 panels
Weathering	--	Total 10 panels	--	Total 9 panels
Post-Weathering Adhesion-Tape	--	3 locations on 1 panel	--	--
Post-Weathering Adhesion-Pull	--	3 panels	--	3 panels

Table 7. Continued

	Liquid Coatings		Reinforced Coatings	
	Interior	Exterior	Interior	Exterior
Post-Weathering Scrub Resistance	--	3 panels	--	3 panels
Post-Weathering Flexibility	--	3 panels	--	3 panels
Post-Weathering Blistering	--	All 10 panels	--	All 9 panels
Post-Weathering Chalking	--	All 10 panels	--	All 9 panels
Total Number of Panels per Product	30	40	28	37
Total Number of Tests per Product	46	78	37	64
Total Number of Panels (615)	180	240	84	111
Total Number of Tests (1047)	276	468	111	192

- **To provide test results on a broad range of coatings, 14 products, as well as 4 replicate products, in four major categories were tested; the breakdown of these products by use category and generic type was presented previously in Table 5.**

- **To assess the variability in test results between laboratories, the entire testing design in Table 7 was performed by two independent laboratories.**

- **To assess variability within a single product due to batch-to-batch differences in laboratory performance and product formulation, the entire set of tests was replicated for one encapsulant product picked at random from each of the four major categories.**

- **To assess variability within a single laboratory and test protocol, at least two replicate tests were performed for each product. Generally, the number of tests per product listed in Table 7 corresponds to the minimum number of replicates recommended in the corresponding ASTM protocol.**

- **Testing of paint products was performed to provide a benchmark for comparison with encapsulant test results. Both high and low quality interior and exterior paints were tested to provide a range of results for this comparison.**

All testing was performed by the Center for Applied Engineering (CAE) in St. Petersburg, Florida and Professional Service Industries (PSI) in Pittsburgh, Pennsylvania. In the past five years CAE conducted over a dozen coatings technology projects involving the testing of coatings on substrates such as aluminum coil stock, cement board, hand railings, and building materials. During that same time PSI conducted nine projects, ranging in duration from one month to two years, that involved testing of coated panels using many of the same ASTM protocols included in this encapsulant testing program. Staff at CAE and PSI include polymer chemists and testing specialists with experience ranging from one year to well over ten years in the testing of various paints and other coatings.

2.5 TEST PANEL SELECTION AND PREPARATION

This section discusses the metal and plastic panels used for testing, as well as application of the coatings to the panels prior to testing. Of particular interest in this section are discussions of problems encountered with the panels during preparation and testing.

2.5.1 Panel Selection

Test panel selection was generally based on specification of the individual ASTM E06.23.30 tests as of December, 1993 and the test method performance data desired by EPA. Table 8 lists the type of panel selected for each test. Several technical issues concerning panel selection arose during the testing. These are discussed in detail test by test. The main issues considered during the initial panel type selection process were test specifications, adhesion, rusting, and availability. ASTM E06.23.30 determined that metal panels generally provided the most uniform and consistent substrate which was readily available.

Adhesion of the products to the sample panel was important to the results of all tests. The encapsulant products are generally not formulated for maximum adhesion to metal substrates. These products are primarily used for covering previously painted surfaces in residential dwellings. Lack of adhesion of a coating to the metal surface of the sample panel might, or might not, provide information about adhesion to previously painted surfaces. Flash rusting during panel preparation, as well as rusting in the weathering cycle and the water immersion test, were of concern in panel selection. Many of the commercial encapsulant products tested in this study were waterborne coatings so flash rusting during panel preparation was a possibility where metal panels were required.

Panels readily available on the commercial market are generally more cost effective and less variable than custom panels. The tin-plated panel favored for eliminating rust concerns was commercially available at a reasonable cost per panel in only one thickness, 0.01 inches. However, this thickness was inadequate to resist deformation during the pull adhesion test (ASTM D 4541). Also, some pin-point rust was seen by CAE after at least one batch of tin-plated steel panels had been coated with product. The panels had passed a visual quality check by the laboratory before use.

Commercial panels for dry abrasion testing (ASTM D 4060) were steel, so flash rusting could occur with waterborne coatings. Zinc phosphate treatment or use of a panel primer could control flash rusting and potentially improve adhesion on the steel panels. ASTM E06.23.30 currently allows use of a specialty primer for the dry abrasion test. A zinc-phosphate treated steel panel was used for the flexibility test (ASTM D 522). This panel did not flash rust or rust during weathering. Zinc-phosphate treated steel panels are available commercially in a variety of thicknesses.

Adhesion to the metal panels selected for testing was not good in some cases. For example, products RE2 and RE3, which were acrylic and polyester composites, did not adhere well to the tin-plated steel panels. In some cases, gentle handling of the prepared panels was sufficient to pop RE2 and RE3 off the test panel. In addition, several products had such poor adhesion during pull adhesion testing (ASTM D 4541) that the dollies pulled the coating off the panels during normal handling. Use of specialty primers would be one approach to improving the adhesion of encapsulant products to test panels.

2.5.2 Panel Preparation

In this study, panels were used "as received" from the vendors. No priming or polishing was done to improve adhesion

unless the primer was always a recommended part of the encapsulant system. Products LN6 and RN3 are two-coat systems that identify the first coat as a primer. Each laboratory prepared its own sample panels according to the specified application method, film thickness, and dry/cure time for each product which were based on manufacturer recommendations. Panels were prepared and dried under the same standard conditions in both laboratories. Minor variations in preparation technique from one laboratory to the other is representative of real-world conditions. Each product was applied at the wet or dry film thickness recommended by the manufacturer because this product thickness should represent the best performance properties of the product. Current commercial encapsulants are recommended for application at a wide range of dry film thicknesses from as thin as 3 mils to as thick as 200 mils.

Table 8. Panel Type Used in This Study With Each ASTM Test

Test Method	Panel Type	Thickness/ inch
Scrub Resistance (D 2486)	Black plastic	N/A
Impact Resistance (D 2794)	Zinc phosphate treated cold-rolled steel	.032
Dry Abrasion Resistance (D 4060)	S-16 specimen plates	4 in. sq.
Viscoelastic Properties (D 2370)	Free films, silicone release paper	N/A
Weathering (G 53)	Tin-plated steel	.01
Flexibility (D 522)	Tin-plated steel	.01
Post-Immersion Blistering (D 714)	Tin-plated steel	.01
Water Immersion (D 1308)	Tin-plated steel	.01
Post-Immersion Tape Adhesion (D 3359)	Tin-plated steel	.01
Post-Immersion Pencil Hardness (D 3363)	Tin-plated steel	.01
Post-Weathering Chalking (D 4214)	Tin-plated steel	.01
Pull Adhesion (D 4541)	Tin-plated steel	.01

As shown in Table 9, a target dry film thickness was recommended for each coat separately. Commercial paints were applied at a dry film thickness of 6±1 mils. Product instructions for reinforced products were not clear as to what effect the thickness of the reinforcing materials would have on

Table 9. Application Parameters for Panel Preparation

Product Code	Number of Coats[(a)]	Application Method	Pot Life[(b)] hrs, ambient	Coat #1		Coat #2	
				Dry Film Thickness Range, mils	Dry/Cure or Recoat Time, hrs	Dry Film Thickness Range, mils	Dry/Cure Time
LE1	1	Drawdown	N/A	6±1	24	N/A	N/A
HPE	1	Drawdown	N/A	6±1	24	N/A	N/A
LE3	1	Drawdown	N/A	6±1	24	N/A	N/A
LE4	1	Drawdown	N/A	7±1	24	N/A	N/A
LE5	1	Drawdown	N/A	6±1	24	N/A	N/A
LPE	1	Drawdown	N/A	6±1	24	N/A	N/A
LN1	1	Drawdown	N/A	6±1	24	N/A	N/A
HPI	1	Drawdown	N/A	6±1	24	N/A	N/A
LN3	2	Drawdown	N/A	6±1	24	6±1	14 days
LN4	1	Drawdown	N/A	6±1	24	N/A	N/A
LN5	2	Drawdown	N/A	6±1	24	6±1	14 days
LN6	2	Drawdown	N/A	6±1	4	6±1	14-30 days
RE1	2	Trowel	2 hrs	65±25	20-40 min	65±25	24 hrs
RE2	2	Drawdown	3 hrs	10±5	3 hrs	10±5	3 hrs
RE3	2	Drawdown	3 hrs	10±5	3 hrs	10±5	3 hrs
RN1	2	Drawdown	4 hrs	10±2	1	10±2	24 hrs
RN2	2	Drawdown	4 hrs	10±2	1	10±2	24 hrs
RN3	2	Drawdown	4 hrs	3±1[(c)]	24	2.5±0.5	7 days

(a) If product was applied in two coats, the thickness of the first coat was measured before application of the second coat.
(b) Useful life of product after opening container.
(c) Applied as two thin layers one hour apart.

the final system thickness. Table 10 shows the target range of system thickness for each product based on the number of coats, thickness of the coats, and presence of reinforcement. Multi-coat products and products including a reinforcing mat had a larger expected range. In some cases, the thickness of the mat was directly additive to the thickness of the coatings. In other cases with porous mats, the presence of a reinforcing material added some thickness to the product system but not a thickness equal to the thickness of the reinforcing material. Products incorporating reinforcing materials were more difficult to prepare in a uniform thickness across the panel. Sample panels for the trowel-applied product (RE1) were much thicker than any of the other products and less uniform in thickness across the panel than sample panels of products applied by drawdown.

The dry/cure time for each product was based on the manufacturer's recommendations (Table 9). However, in three cases impact tests at PSI were run before the full cure time recommended: LN3 panels were tested after 7 days rather than the full 15 day period; LN5 panels were tested after 10 days rather than the full 15 day period; LN6 panels were tested after 6 days rather than the full 14-30 day range. It should also be noted that this discrepancy did not appear to significantly affect the impact resistance testing results for these three products (see Figure 14 of Section 4.8).

As shown in the last two columns of Table 10, some problems were encountered with preparing systems to the specified thickness. The most significant problems are highlighted below:

- For product LE4 (acrylic liquid exterior encapsulant) tested at CAE, 13 of 42 system thicknesses were out of the range and all were too thin;
- For the trowel applied cementitious product RE1 tested at CAE, 29 of 38 system thicknesses were out of the range and all were too thick;

Table 10. Product System Target Thickness

Product Code	Number of Coats	Application Method	Thickness (mils)			Target Range (mils)	No. of Results in Range	
			Mat	Coat 1	Coat 2		CAE	PSI
LE1	1	Draw-Down		6±1	--	5-7	42/42	32/41
HPE	1	Draw-Down		6±1	--	5-7	42/42	41/41
LE3	1	Draw-Down		6±1	--	5-7	39/42	31/41
LE4	1	Draw-Down		7±1	--	6-8	29/42	25/41
LE5	1	Draw-Down		6±1	--	5-7	41/42	36/41
LPE	1	Draw-Down		6±1	--	5-7	42/42	38/41
LN1	1	Draw-Down		6±1	--	5-7	32/32	31/31
HPI	1	Draw-Down		6±1	--	5-7	32/32	29/30
LN3	2	Draw-Down		6±1	6±1	10-14	32/32	32/32
LPI	1	Draw-Down		6±1	--	5-7	32/32	17/31
LN5	2	Draw-Down		6±1	6±1	10-14	31/32	28/31
LN6	2	Draw-Down		6±1	6±1	10-14	31/32	31/31
RE1	2	Trowel	15±1	65±25	65±25	80-196*	9/38	37/37
RE2	2	Draw-Down	6±1	10±5	10±5	10-37*	38/38	38/38
RE3	2	Draw-Down	6±1	10±5	10±5	10-37*	37/38	38/38
RN1	2	Draw-Down	5±1	10±2	10±2	16-30*	29/29	27/28
RN2	2	Draw-Down	5±1	10±2	10±2	16-30*	29/29	29/29
RN3	2	Draw-Down	6±1	3±1	3±1	5-15*	25/29	10/29
TOTAL							592/643	550/617

*The thickness of the reinforcing mat may, or may not, add directly to the final product system thickness so targets allow for a possible range.

- **For product LE4 (acrylic liquid exterior encapsulant) tested at PSI, 16 of 41 system thicknesses were out of the range, both on the thin and thick sides;**
- **For product LPI (vinyl latex, low quality interior paint) tested at PSI, 14 of 31 system thicknesses were out of the range and all were too thick;**
- **For product RN3 (epoxy reinforced interior encapsulant) tested at PSI, 19 of 29 system thicknesses were out of the range and all were too thick.**

Although system thickness was not a performance property in and of itself, differences in thickness can affect the results of several ASTM tests discussed later.

3.0 DATA ANALYSIS APPROACH

Because this was a pilot testing program, information was collected at two different levels. First, a qualitative assessment was made of the feasibility of using the targeted ASTM test protocols on this set of new encapsulant products. And second, quantitative statistical analyses were performed on the testing results whenever possible, that is, whenever a sufficient number of results could be collected.

3.1 QUALITATIVE ASSESSMENT OF TEST METHODS

Encapsulants for leaded paint represent a very broad range of coatings. Some encapsulants are much like paint and other architectural coatings; however, other encapsulants, like reinforced and cementitious products, are quite different from these coatings. Therefore, while the performance of ASTM test protocols with standard coatings is relatively well documented, the ability of these protocols to test other encapsulants is still very much in question.

As a result, this study first evaluated the practical viability of the ASTM protocols for testing encapsulants. Each test protocol was examined on two levels: (1) could the test method be successfully performed as proposed, and (2) did the test results provide information that could be used to establish a reliable level of performance for encapsulants?

A number of technical challenges were encountered in completing the standard ASTM test methods with the diverse product group being tested. Product physical and chemical properties, panel thickness, panel selection, equipment limitations, and proposed test parameters affected the laboratory's ability to perform the test protocols. Each test method had to be considered not only individually but also in combination with other protocols as proposed by the ASTM E06.23.30 Task Group. Combinations of tests sometimes resulted in practical problems. For example, scrub resistance testing could be run according to ASTM D 2486 on unexposed panels. However, the same test produced several technical challenges in evaluating panels after the weathering cycle. The commercial black plastic test panels were too large to fit in the weathering test chamber sample holders, and also deformed in the heat. The technical issues encountered with conducting each test method are discussed in detail test by test in Chapter 4.

A second qualitative assessment concerned whether or not the test results provided information useful in establishing performance requirements or grouping encapsulant product systems. Did the proposed test provide repeatable data that could be used to distinguish among different encapsulant and paint products? For example, the tape adhesion test (ASTM D 3359) had a limited ability to differentiate among products. Most liquid products had similar ratings on the 0-5 test scale and the test was not usable on the reinforced products. Performance of the encapsulant systems on each test is also discussed in detail test by test in Chapter 4.

3.2 STATISTICAL ANALYSIS OF TEST RESULTS

As the initial step in the data analysis, descriptive statistics were calculated for all of the test results. The summary statistics included the total number of tests performed; the number of missing data; the minimum, maximum, and mean result obtained; and the standard deviation of the measurements. The summary statistics were calculated across all appropriate groupings of the data. For each test these groupings included (1) across replicate test panels, (2) across replicate encapsulant products, and (3) across the two testing laboratories. In addition, the data were grouped across different coatings within the liquid and reinforced categories.

Detailed statistical analyses of the test results were also performed related to each of the following objectives:

- Compare the test results with current ASTM E06.23.30 standards to help assess the appropriateness of those standards.
- Assess differences in test results between the two testing laboratories.
- Assess differences in the test results within a single laboratory for replicate test panels and between replicate encapsulants.
- Assess the ability of each test method to distinguish among groupings of products.

In many cases the test results were evaluated with formal statistical testing procedures. However, in some cases, such as when comparing the test results against the ASTM E06.23.30 standards and when assessing differences between the two laboratories, the evaluation was based on simple comparisons, rather than formal testing, of the statistical results.

For each of the quantitative test results (e.g., dry abrasion, pull adhesion, flexibility), an analysis of variance model was fitted to the data to estimate differences between the different types of coatings, as well as to estimate variability between replicate test panels. The statistical model has the following form:

$$T_{ij} = \alpha + C_i + \varepsilon_{ij}$$

for

$i = 1,...,12$ liquid coatings (or 6 reinforced coatings)
$j = 1,...,J$ replicate tests (from 2-5 replicates, see Table 7)

where

T_{ij} = test result measured for the i-th coating and the j-th replicate test panel

α = overall average test result across all coatings and panels

C_i = fixed effect for the i-th coating which is defined as the difference between the average test result for all coatings and the average test result for the i-th coating

ε_{ij} = random effect for variability among replicate test panels; assumed to follow a normal distribution with mean zero and standard deviation σ_ε

In the analysis a separate model was fitted for the test results from each of the two laboratories and for the liquid versus reinforced coatings (i.e., four data groupings). In the model, α corresponds to the average result from all tests run within each of the four data groupings. The term C_i allows for a different average test result for each product, and the term ε_{ij} accounts for variability among test results repeated for a single product on more than one test panel.

The statistical models were fitted to the data for each type of test using the SAS® general linear models procedure (PROC GLM). Results from the model fit include point estimates for the fixed model parameter α, as well as for the replicate test panel variance component σ_ε. In addition, a shotgun F-test was run to determine if any of the product means was significantly different from the others, and the following contrasts and comparisons were computed:

- **Contrast jointly comparing the average test results between the replicate encapsulants**

$$[LE3 - LE5]\ ,\ [LN3 - LN5]$$

- **Contrast comparing the average encapsulant test result with the average paint result**

$$\frac{1}{6}\left[LE1 + \frac{LE3}{2} + LE4 + \frac{LE5}{2} + LN1 + \frac{LN3}{2} + \frac{LN5}{2} + LN6 \right] - \frac{3}{2}\left[LE2 + LE6 + LN2 + LN4\right]$$

- **Multiple pairwise comparisons of all product means, to determine if each test appears capable of distinguishing among groups of products.**

For each of these contrasts and comparisons tests of statistical significance were also performed and reported, and results which were significant at the 5% and 1% levels were highlighted. Note that for the first contrast listed, an analogous expression was used for the replicate reinforced products. Also, note that for the second contrast listed above, the expression shown applies to non-weathering tests run on all 12 liquid products. An analogous expression involving just the 6 liquid exterior products was used for the weathering test results.

Estimation of the replicate test panel variance component and the contrast comparing average test results between replicate encapsulant products was used to help meet the third quantitative analysis objective of assessing test results within a single laboratory. Estimation of the contrast comparing the average encapsulant test result with the average paint result, as well as the multiple pairwise comparisons analysis and shotgun F-test, were performed to help meet the fourth quantitative objective of assessing whether each test method was able to distinguish among groupings of products.

Assessment of Performance Standards

Ultimately, performance standards will have to be established for a selected set of tests which measure important physical properties of encapsulants. The performance standard for a particular test will be a predetermined value which the testing results for a given coating product must equal or exceed so that the product may be classified as an approved encapsulant. For example, ASTM E06.23.30 has proposed a draft standard of 1200 cycles for the scrub resistance test when used to evaluate liquid encapsulants. This means that if a product is tested with the scrubbing protocol and lasts 1200 cycles or more without wearing through to the substrate, then it passes the scrub test, which is one of several tests that a product must pass to become an approved encapsulant.

ASTM Task Group E06.23.30 has been working for several months to reach consensus on a set of minimum performance standards for liquid encapsulants, and their findings are currently moving through the ASTM approval process (2). ASTM E06.23.30 has also been working on a set of draft standards for reinforced encapsulants, but these standards have not yet been agreed upon by the Task Group (3) even in draft form. The results from this current EPA study provide a wealth of information to help assess the appropriateness of the ASTM standards.

This report helps assess the ASTM standards by summarizing for each test the number of encapsulant and paint products which passed the ASTM standard. In addition, where appropriate, interesting trends are noted about the kinds of products which did not pass the standard. This assessment is more qualitative than statistical. And, it is not intended to assess individual products, but rather to help assess how the standards have been set relative to the range of testing results that might be expected from future testing at other laboratories. Since this

EPA study included only a limited number of encapsulant and paint products, the test results can not provide an accurate evaluation of the number and types of products which are likely to pass the standard in the future.

Assessment of Laboratory Differences

One common source of variability that can affect the testing results is related to differences introduced by the laboratory conducting the tests. Numerous factors can affect laboratory performance including equipment, staff experience and training, and internal quality assurance procedures. Ideally, this source of variability would be assessed by conducting identical tests on the same products at several different laboratories. However, limited resources for this pilot study limited the number of laboratories to two. Therefore, the assessment of laboratory differences was addressed by independently analyzing the data for each laboratory, and then simply qualitatively comparing the statistical findings. If more laboratories had been included, then an additional variance component could have been added to the statistical model and estimated.

Assessment of Variability Within a Single Laboratory

Within a single laboratory, one common source of testing variability is related to differences introduced through test panel preparation and then measurement of the physical properties associated with each panel. In this study this source of variability is called measurement variability. A second common source of testing variability is related to differences introduced by the chemical formulation of the specific product sample that is tested. In this study this second source of variability is called replicate product variability.

Measurement variability was generally estimated in this study by testing two or more panels or free films that were all prepared using the same product sample. This variability was statistically quantified by the replicate test panel variance component σ_ε. The one exception to this approach was tape adhesion testing where the three replicate tests were performed on a single test panel. Replicate product variability was estimated by testing two different sets of panels that were prepared with two different samples of the same product. This second source of variability was statistically quantified by the first contrast listed above. Interpretation of the estimates of measurement variability and replicate product variability involved testing the statistical significance of the estimates to determine whether these sources of variability were significantly different from zero or not.

Assessment of Whether the Test Methods are Able to Distinguish Among Groupings of Products

Clearly, the most important function of the encapsulant testing protocols is to simply determine which products can pass minimum performance standards. However, from a statistical point of view, tests which also have the ability to distinguish among different groupings of products may provide a more sensitive measure of performance. Therefore, the shotgun F-test, the second contrast listed above, and the multiple comparisons analysis were performed to see which tests might be able to distinguish groupings of products.

The shotgun F-test examined the null hypothesis that the average test results for all of the products tested were equal, versus the alternative hypothesis that the average test result for at least one product was different. When the null hypothesis was accepted, this was an indication that the test could not distinguish among the results for any of the products, and that therefore no groupings among products could be found. However, when the null hypothesis was rejected this indicated that some groupings were possible, and the multiple comparisons analysis was performed to find those groupings.

The purpose of estimating the second contrast was to help see whether the liquid encapsulants, when taken as a group, could be distinguished through the test results from the paints taken as a group. However, it should be noted that even if the average encapsulant test result was different from the average paint result, it could be that test results for some encapsulants were still quite similar to test results for some paints. That is, in some cases two groups can not be unambiguously distinguished, even if their average test results are different. Interpretation of the encapsulant versus paint contrast first involved judging its statistical significance. If the contrast was found to be significant, this indicated that the average encapsulant test result was significantly different from the average paint test result. If this was the case, the magnitude of the estimated contrast could be examined to see how large the differences between encapsulants and paints typically were.

Analysis of Semi-Quantitative and Qualitative Results

As a first approximation the following semi-quantitative or qualitative test results were recoded to a numerical scale and analyzed as if they were true quantitative results:

- Tape adhesion ratings 0A to 5A were recoded to numerical scale 0-5 where the value 0 represents complete separation of the coating from the panel, while the value 5 represents no loss of coating.
- Blistering ratings 0 to 10 representing the size of blisters were assumed to represent numerical scale 0-10; however, the value 10 represents no blisters, while the value 0 represents very large blisters. Also, the letter designations indicating the number of blisters were not considered in the statistical analysis.

- Chalking ratings 0 to 10 were assumed to represent numerical scale 0-10; however, the value 10 represents no chalking, while the value 0 represents the greatest degree of chalking.

- Pencil hardness ratings 6B to 6H were recoded to numerical scale 0-13 where the values 6B and 0 represent the softest coatings, while the values 6H and 13 represent the hardest coatings.

These first approximations implicitly assume a linear increase between successive semi-quantitative or qualitative ratings. For example, the change in coating hardness from 6B to 5B is assumed to be the same as the change in hardness between all other successive ratings, such as 5H to 6H. This assumption was made for statistical purposes only. These relationships have not been quantified in the laboratory. In addition, although non-parametric statistical procedures might also have been used to analysis these results, the data were judged quantitative enough to be analyzed with parametric methods.

4.0 STUDY RESULTS

This section presents the results of the encapsulant pilot testing program. In the first subsection data completeness is addressed in terms of meeting the data quality objective listed in Section 2.1. Then, qualitative and quantitative assessments are made of each ASTM test protocol in turn.

4.1 OVERALL DATA COMPLETENESS

The data quality objective for this program was to obtain 95% data completeness across the battery of ASTM tests listed in Section 2.4. In most cases, actual quantitative measurements were reported by the laboratories. However, realizing that this was a pilot testing program subjecting encapsulation products to ASTM protocols for perhaps the first time, there were several cases in which quantitative measurements could not be obtained because the ASTM test could not be conducted as designed. In those cases the laboratories reported information on the problems encountered conducting the tests, and those instances were recorded as cases where the laboratories were "unable to test" the products. These cases are considered as valid test results in this study, and are distinguished from cases of "missing results" where data may have been lost, miscalculated, etc.

Table 11 summarizes overall data completeness for this study, as well as data completeness for each test separately. The number of results expected from each laboratory is first listed, followed by a tabulation of the number of valid results obtained and the number of results missing. As noted above, the number of valid results is differentiated into the number of "measured data" versus the number of cases which the laboratory was "unable to test." In all cases the data completeness figures are also broken down by laboratory.

The overall data completeness achieved in this study was 96.4%, and consisted of 3674 measured data (excluding 46 extra

dry film thicknesses which were reported) and 133 cases which the laboratories were unable to test. This data completeness

Table 11. Summary of Data Completeness

Test Type	Number of Results Expected per Lab	Number of Valid Results				Number of Missing Results	
		Measured Data		Unable to Test			
		CAE	PSI	CAE	PSI	CAE	PSI
Dry Film Thickness	615	643[1]	617[2]	--	--	2	14
Tape Adhesion							
Unexposed panels	36	36	34	--	2	--	--
Immersed panels	36	36	36	--	--	--	--
Weathered panels	18	18	9	--	9	--	--
Pull Adhesion							
Unexposed panels	54	54	51	--	3	--	--
10 min. after immersion	36	33	--	3	36	--	--
120 min. after immersion	18	16	--	2	18	--	--
Weathered panels	27	25	26	2	1	--	--
Scrub Resistance							
Unexposed panels	54	53	54	1	--	--	--
Weathered panels	27	22	10	5	17	--	--
Flexibility							
Unexposed panels	54	51	51	3	3	--	--
Weathered panels	27	21	23	6	4	--	--
Impact Resistance							
Unexposed panels	18	18	18	--	--	--	--
Dry Abrasion Resistance							
Unexposed panels							
Endpoint	36	34	34	--	--	2	2
Loss at 1000 cycles	36	36	34	--	1	--	1
Loss at endpoint	36	34	34	--	--	2	2
Wear index	36	34	34	--	--	2	2
Viscoelastic Properties							

Table 11. Continued

Test Type	Number of Results Expected per Lab	Number of Valid Results				Number of Missing Results	
		Measured Data		Unable to Test			
		CAE	PSI	CAE	PSI	CAE	PSI
Unexposed films							
Tensile strength	90	90	89	--	--	--	1
Elongation	90	90	89	--	--	--	1
Stiffness	90	85	84	4	5	1	1
Blistering							
Immersed panels	66	65	66	1	--	--	
Weathered panels	87	87	87	--	--	--	
Chalking							
Weathered panels	87	86	87	1	--	--	
Pencil Hardness							
Unexposed panels	144	142	36	2	--	--	108
10 min. after immersion	96	96	96	--	--	--	--
120 min. after immersion	60	56	60	4	--	--	--
Total	1974	1961[3]	1759[3]	34	99	9	132

1 18 extra panels (1 panel per product) were prepared to complete the unexposed pencil hardness test, and 12 extra panels (1 panel per liquid product) were prepared to complete the immersed pencil hardness test, yielding a total of 30 extra dry film thickness results.

2 16 extra panels (across 15 different products) were prepared and measured, but were not used for other testing, yielding a total of 16 extra dry film thickness results.

3 Includes extra dry film thickness results.

exceeded the 95% data quality objective. Both laboratories were able to supply approximately the same number of test results, although PSI experienced a higher number of cases where they were unable to test, as well as a higher number of missing results. The most significant testing problem experienced by PSI was related to the pencil hardness test for unexposed panels where they misunderstood the study design and neglected to test unexposed panels for hardness. Among the various tests, pull adhesion resulted in the highest number of cases which were unable to test, particularly when run in combination with water immersion. Scrub resistance run after weathering, as well as flexibility, also resulted in several cases which were unable to test. Where appropriate, additional discussion of testing difficulties for different products is provided in the following sections on individual test results.

4.2 OVERALL SUMMARY STATISTICS

As discussed earlier, the initial step in the data analysis was to calculate various summary statistics which are presented in Table 12. Note that these results do not necessarily differentiate potentially important differences between laboratories, between individual products, nor between replicate products. In this table the data are pooled and equally weighted within only two broad categories, liquid versus reinforced coatings.

The number of data (N) included in each set of calculations corresponds to the number of valid measured data presented earlier in Table 11, although in Table 12 these numbers are broken down by liquid versus reinforced coatings, while in Table 11 the numbers are broken down by laboratory. The minimum (Min) and maximum (Max) observed results provide a measure of the range in the data, while the mean provides a measure of the central tendency. The standard deviation (Std. Dev.) quantifies the

spread in the data, and is also presented as a percentage of the mean (in parentheses). Note that for some tests (e.g., adhesion,

Table 12. Summary Statistics for ASTM Test Results

Test Type	Liquid Coatings					Reinforced Coatings				
	N	Min	Max	Mean	Std. Dev. (% of Mean)	N	Min	Max	Mean	Std. Dev. (% of Mean)
Dry Film Thickness (mils)	861	4.0	15.0	7.3	2.5(34%)	399	11.6	343.5	51.1	75.1(147%)
Tape Adhesion (0-5 rating)										
Unexposed panels	70	0	5	4	1.6(40%)	--	--	--	--	--
Immersed panels	72	0	5	3	2.4(80%)	--	--	--	--	--
Weathered panels	27	1	5	5	1.3(26%)	--	--	--	--	--
Pull Adhesion (psi)										
Unexposed panels	72	0	700	200	158(79%)	33	0	500	200	135(68%)
10 min. after immersion	23	0	500	200	146(73%)	10	0	500	200	151(76%)
120 min. after immersion	11	0	500	300	169(56%)	5	200	400	300	71(24%)
Weathered panels	35	0	600	200	166(83%)	16	0	290	0	99(--)
Scrub Resistance (cycles)										
Unexposed panels	72	154	5000	3846	1597(42%)	35	5000	5000	5000	0(0%)
Weathered panels	16	4031	5000	4914	256(5%)	16	5000	5000	5000	0(0%)
Flexibility (crack length inches)										
Unexposed panels	72	0	0.43	0.24	0.08(33%)	30	0	6.0	1.8	2.4(133%)
Weathered panels	36	0	1.94	0.16	0.48(300%)	8	3	6.0	4.5	0(0%)
Impact Resistance (inch-lbs.)										
Unexposed panels	24	24	160	116	51(44%)	12	16	160	87	70(80%)
Dry Abrasion Resistance										
Unexposed panels										
Endpoint (cycles)	48	600	5000	3238	1346(42%)	20	5000	5000	5000	0(0%)
Loss at 1000 cycles (g)	47	0.07	0.55	0.21	0.09(43%)	23	0.01	0.23	0.14	0.06(43%)
Loss at endpoint (g)	48	0.22	1.33	0.59	0.19(32%)	20	0.06	0.95	0.52	0.22(42%)
Wear index (g/1000 cycles)	48	0.04	0.59	0.22	0.11(50%)	20	0.01	0.19	0.10	0.04(40%)
Viscoelastic Properties										
Free films										
Tensile strength (psi)	119	121	2131	580	408(70%)	60	812	7378	3366	1547(46%)
Elongation (%)	119	1	1091	171	194(113%)	60	1	30	10	8(80%)
Stiffness (psi)	109	10	908	233	212(91%)	60	436	7000	2101	1748(83%)
Blistering (0-10 rating)										
Immersed panels	96	0	10	6	3.5(58%)	35	10	10	10	0(0%)
Weathered panels	120	2	10	10	1.8(18%)	54	10	10	10	0(0%)
Chalking (0-10 rating)										
Weathered panels	119	6	10	8	0.9(11%)	54	6	10	8	1.1(14%)
Pencil Hardness (0-13 rating)										
Unexposed panels	120	2	7	6	1.0(17%)	58	4	13	9	3.8(42%)
10 min. after immersion	144	0	9	0	1.3(--)	48	0	13	8	6.0(75%)
120 min. after immersion	94	0	13	2	2.4(120%)	22	0	13	7	6.2(89%)

scrub resistance, dry abrasion end point) better performance is indicated by larger data values, while for other tests (e.g., flexibility, dry abrasion weight loss and wear index) better performance is indicated by smaller data values.

In order to provide most of the statistical results at one location for easy reference in this report, Table 13 is also presented in this section. This table lists most of the results from fitting statistical models to the data (see Section 3.2 for additional details on the statistical models). Specifically, the following estimates are shown in Table 13 for each laboratory separately:

- the estimated mean ($\hat{\alpha}$)
- the estimated measurement variability ($\hat{\sigma}_{\varepsilon}$), also expressed as a percentage of the mean
- the p-value for the shotgun F-test, which indicates whether any of the product means was significantly different from the others
- the estimated contrast (Encap. vs. Paint), which compares the average encapsulant result with the average paint result
- the estimated contrast (Ext. Reps), which compares the average results for the two replicate exterior encapsulant products
- the estimated contrast (Int. Reps), which compares the average results for the two replicate interior encapsulant products.

In this table significant results (5% significance level) are indicated by one star () and highly significant results (1% significance level) by two stars (). It should also be noted that the test of equality for the replicate products is a joint test which considers together the differences between both the exterior and interior replicates. Therefore, this test will

prove significant if either both sets of replicates are different, or if one of the two sets of replicates is highly different.

Table 13. Statistical Modeling Results

Test Type	Lab	Liquid Coatings						Reinforced Coatings				
		Mean	Measurement Variability (% of Mean)[1]	F-test Product Means[2]	Encap. vs. Paint[3]	Ext. Reps[4]	Int. Reps[5]	Mean	Measurement Variability (% of Mean)[1]	F-Test Product Means[2]	Ext. Reps[4]	Int. Reps[5]
Dry Film Thickness (mils)	CAE	7.0	0.6(8%)	.0001**	2.2**	0.7**	0.5**	64.3	25.2 (39%)	.0001**	0.5	0.4
	PSI	7.7	1.0(13%)	.0001**	2.2**	0.2**	0.8**	37.9	7.5 (20%)	.0001**	0.6	0.9
Tape Adhesion (0-5 rating)												
Unexposed panels	CAE	5	0(0%)	--	1	0	0	--	--	--	--	--
	PSI	4	0.2(5%)	.0001**	2**	5**	0**	--	--	--	--	--
Immersed panels	CAE	4	0(0%)	--	3	0	0	--	--	--	--	--
	PSI	2	0(0%)	--	1	0	0	--	--	--	--	--
Weathered Panels	CAE	5	0(0%)	--	0	0	--	--	--	--	--	--
	PSI	4	0(0%)	--	2	--	--	--	--	--	--	--
Pull Adhesion (psi)												
Unexposed panels	CAE	300	141(47%)	.0115*	200**	100	0	200	127(64%)	.0796	100	0
	PSI	140	45(32%)	.0001**	150**	90	0	170	81(48%)	.1645	80	70
10 min. after immersion	CAE	200	111(56%)	.0761	200**	100	0	200	94(47%)	.1074	100	100
	PSI	--	--	--	--	--	--	--	--	--	--	--
120 min. after immersion	CAE	300	--	--	300	300	100	300	--	--	100	0
	PSI	--	--	--	--	--	--	--	--	--	--	--
Weathered panels	CAE	300	137(46%)	.0162*	200**	100	--	0	0(0%)	--	0	--
	PSI	170	52(31%)	.0004**	160**	50	--	90	41(46%)	.0006**	0	--
Scrub Resistance (cycles)												
Unexposed panels	CAE	3459	259(7%)	.0001**	2971**	343	0	5000	0(0%)	--	0	0
	PSI	4232	414(10%)	.0001**	2161**	0	400	5000	0(0%)	--	0	0
Weathered panels	CAE	4894	109(2%)	.0013**	417**	0	--	5000	0(0%)	--	0	--
	PSI	5000	0(0%)	--	--	0	--	5000	0(0%)	--	0	--
Flexibility (crack length inches)												
Unexposed panels	CAE	0.02	0.02(100%)	.0001**	-0.06**	0	0	1.2	0(0%)	--	0	0
	PSI	0.03	0.02(67%)	.0001**	-0.08**	0	0	2.4	0(0%)	--	0	0
Weathered panels	CAE	0.28	0.10(36%)	.0001**	-0.83**	0	--	3.0	0(0%)	--	0	--
	PSI	0.05	0.16(320%)	.2386	-0.15	0	--	6.0	0(0%)	--	0	--
Impact Resistance (inch-lbs.)												
Unexposed panels	CAE	128	--	--	80	0	0	105	--	--	4	0
	PSI	104	--	--	68	28	20	68	--	--	0	0
Dry Abrasion Resistance												
Unexposed panels												
Endpoint (cycles)	CAE	3246	380(12%)	.0001**	838**	648	599	5000	0(0%)	--	0	0
	PSI	3230	469(15%)	.0001**	1456**	1350*	0*	5000	0(0%)	--	0	0
Loss at 1000 cycles (g)	CAE	0.21	0.02(10%)	.0001**	-0.04**	0	0.02	0.14	0.03(21%)	.4147	0.03	0.02
	PSI	0.20	0.03(15%)	.0001**	-0.05**	0.07	0.05	0.14	0.02(14%)	.0018**	0.00	0.06
Loss at Endpoint (g)	CAE	0.61	0.06(10%)	.0001**	0.01	0.01	0.12	0.49	0.11(22%)	.9528	0.05	0.03
	PSI	0.57	0.22(39%)	.5112	-0.04	0.12	0.43	0.54	0.10(19%)	.0033**	0.18	0.32*
Wear Index (g/1000 cycles)	CAE	0.21	0.02(10%)	.0001**	-0.04**	0.03	0.05	0.10	0.02(20%)	.9528	0.01	0.01
	PSI	0.22	0.05(23%)	.0001**	-0.07**	0.07	0.09	0.11	0.02(18%)	.0033**	0.04	0.06*
Viscoelastic Properties												
Free Films												
Tensile Strength (psi)	CAE	685	33(5%)	.0001**	-398**	53**	150**	3996	1107(28%)	.0001**	103	125
	PSI	472	71(15%)	.0001**	14	30*	126*	2737	301(11%)	.0001**	82	446
Elongation (%)	CAE	163	44(27%)	.0001**	186**	59**	187**	9	6(67%)	.0079**	1	1
	PSI	179	152(85%)	.0001**	207**	244**	226**	12	4(33%)	.0001**	2**	9**
Stiffness (psi)	CAE	263	45(17%)	.0001**	-230**	2**	103**	3115	1388(45%)	.0004**	411	186
	PSI	202	46(23%)	.0001**	-154**	--	68*	1087	247(23%)	.0001**	325	131

Table 13. Continued

Test Type	Lab	Liquid Coatings Mean	Measurement Variability (% of Mean)[1]	F-test Product Means[2]	Encap. vs. Paint[3]	Ext. Reps[4]	Int. Reps[5]	Reinforced Coatings Mean	Measurement Variability (% of Mean)[1]	F-Test Product Means[2]	Ext. Reps[4]	Int. Reps[5]
Blistering (0-10 rating)												
Immersed panels	CAE	7	1.0(14%)	.0001**	1*	0	1	10	0(0%)	--	0	0
	PSI	5	3.3(66%)	.1406	-1	1	2	10	0(0%)	--	0	0
Weathered panels	CAE	10	0(0%)	--	0	0	--	10	0(0%)	--	0	--
	PSI	9	1.3(14%)	.0001**	3**	0	--	10	0(0%)	--	0	--
Chalking (0-10 rating)												
Weathered panels	CAE	8	0.6(8%)	.0001**	1**	0	--	8	0.5(6%)	.0001**	0	--
	PSI	8	0.1(1%)	.0001**	0**	0	--	8	0.4(5%)	.0007**	0	--
Pencil Hardness (0-13 rating)												
Unexposed panels	CAE	6	0.4(7%)	.0001**	0	1**	0**	9	0.3(3%)	.0001**	0**	1**
	PSI	4	0.2(5%)	.0001**	1**	2**	0**	10	0.6(6%)	.0001**	0	0
10 min. after immersion	CAE	0	0(0%)	--	0	0	0	7	0.2(3%)	.0001**	0	0
	PSI	1	1.3(130%)	.0001**	0	1	0	8	1.6(20%)	.0001**	0	0
120 min. after immersion	CAE	2	1.4(70%)	.0011**	-1	3*	1*	6	0(0%)	--	--	0
	PSI	1	2.2(220%)	.0008**	-1	0	1	7	0(0%)	--	0	1

* Significant at the 5% level.
** Significant at the 1% level.

1 The estimated measurement variability $(\hat{\sigma}_{\varepsilon})$, also expressed as a percentage of the mean.
2 The shotgun F-test statistic which tests the equality of all product means.

3 The contrast which compares the average encapsulant result with the average paint result.
4 The contrast which compares the average results for the two exterior encapsulant products.
5 The contrast which compares the average results for the two interior encapsulant products.

The results presented in Tables 11, 12, and 13 are discussed test by test in the sections that follow. Also, the results from the multiple comparisons analysis are presented in separate tables in the following sections.

4.3 DRY FILM THICKNESS

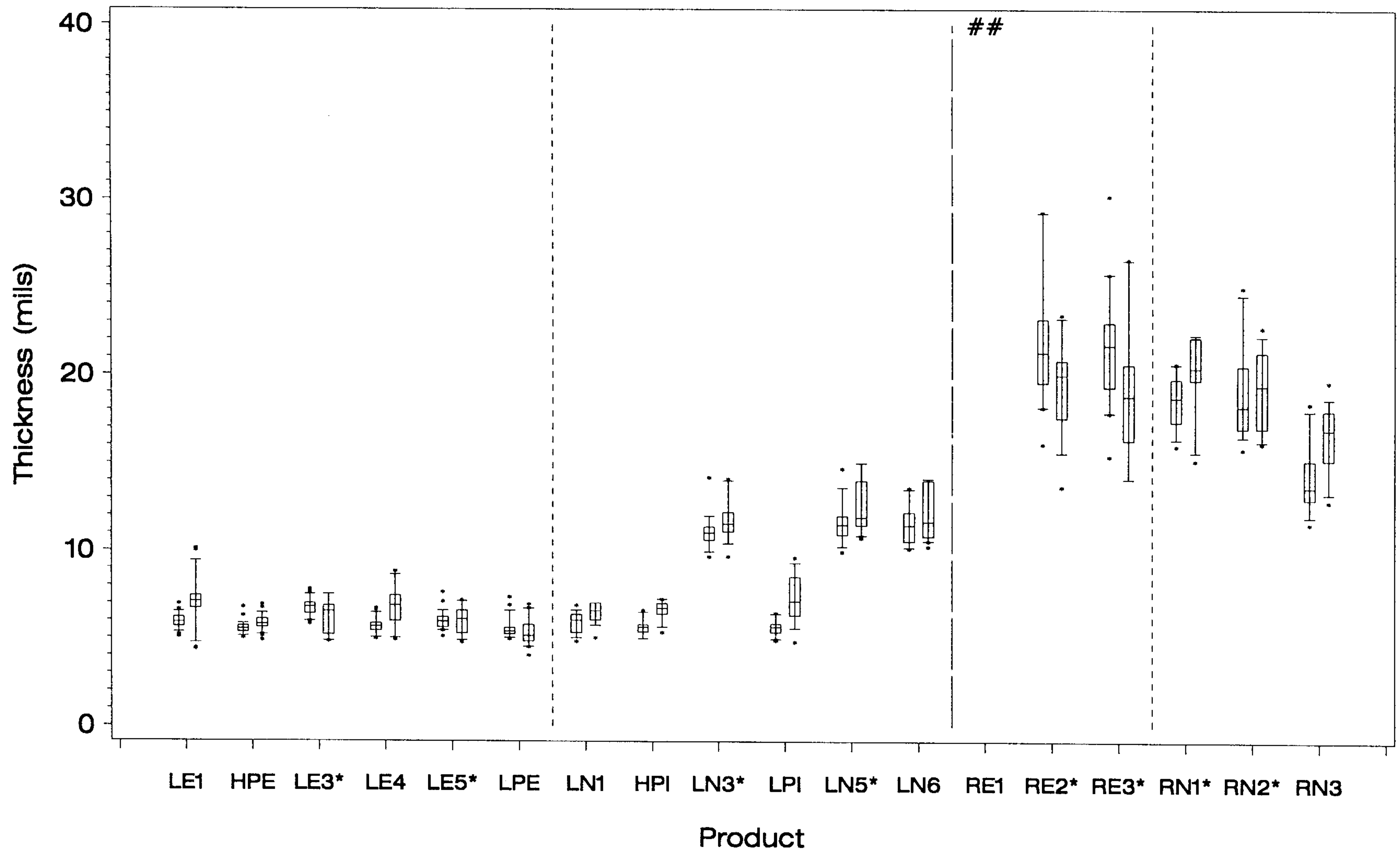
Although dry film thickness is not a physical property that is used to distinguish encapsulant product performance, the thickness of each coating or encapsulant system is an important factor that may potentially affect the results of other performance tests. Therefore, the dry film, or system, thickness data are summarized in this section.

Two test methods (ASTM D 1005 and D 1186) were selected for measuring dry film thickness because samples to be measured included films on metal panels, films on plastic panels, and free films. It was also necessary to use more than one type of micrometer to accommodate the thickness range of 4 mils to 344 mils in the test panels for this study. Micrometers must be properly calibrated and used to measure film thicknesses appropriate to instrument capabilities. In this study the type of micrometer did not affect the thickness determinations because the micrometers were selected to provide the desired sensitivity (number of significant figures) and the micrometers were properly calibrated.

The products in this study were applied to the sample panels at thicknesses recommended by the product manufacturer. Figure 1 provides an overview of final system thickness for all sample panels in the form of a box and whisker plot for each product and each laboratory. The upper and lower edges of each box represent the 75th and 25th percentiles, respectively, of the frequency distribution of the dry film thicknesses for that product. The ends of the line segments extending out of the top and bottom of each box represent the 95th and 5th percentiles, respectively;

and the line segment through the middle of each box represents the median. Extreme measurements above the 95th percentile or

Figure 1
Dry System Thickness Results for All Panels and Free Films



RE1 thicknesses range between 162 – 344 mils for CAE and between 89 – 170 mils for PSI.

below the 5th percentile are plotted as individual points. Furthermore, for each product there are two box and whisker plots shown, corresponding to the measurements for each of the two testing laboratories. The CAE results are shown as the left-hand member of each pair, while the PSI results are the right-hand member.

It is also important to understand the product codes which are utilized in this figure, as well as most other figures in this report. The product types were described earlier in Table 6. The high-quality and low-quality exterior and interior paints are denoted as products HPE, LPE, HPI, and LPI respectively. Liquid exterior encapsulants have codes beginning with LE, liquid interior encapsulants have codes beginning with LN, reinforced exterior encapsulants have codes beginning with RE, and reinforced interior encapsulants have codes beginning with RN. Within each of these four product categories, the two replicate encapsulants are denoted by a star () at the end of their codes.

As shown earlier in Table 11 data completeness was good for the dry film thickness information. The following were the only missing data:

- CAE did not report thickness data for two panels, one for product LN6 and the other for product RE3. In the latter case the coating did not adhere to the panel sufficiently to be tested.
- PSI did not report thickness data for 14 films used for viscoelastic properties testing. Of these, six LE3 and five LE5 films were not obtained intact, and one film each for LE6, LN2, and LN4 broke prior to testing.

As discussed in Section 2.5.2, the 18 products tested in this program ranged widely from thicknesses of a few mils which are typical of paints, to thicknesses one or two orders of magnitude higher which are typical of cement or mortar. Also, in some encapsulant systems, the final dry film thickness included one or two coats, as well as the reinforcing material, if present.

Although thickness is not a property that will be used to judge product performance, the statistical modeling results in Table 13 do indicate several points related to the system thicknesses which confirm the target ranges and which should be considered when interpreting the test results in later sections. These results can be summarized as follows:

- The target thicknesses varied significantly for the products tested. For example, on average the liquid encapsulants were 2.2 mils thicker than the paints, due to the fact that three encapsulants (LN3, LN5, and LN6) were two-coat systems. These thickness differences may affect other test results discussed in later sections.

- The measurement variability among replicate test panels for the liquid coatings was reasonably small, representing from 8% to 13% of the mean. Most of this variability was probably associated with preparation differences from panel to panel for the same product. These differences were on the order of 0.7 mils, and were the same order of magnitude seen between replicate liquid products (about 0.6 mils). It should be noted, however, that these differences are averaged across both one-coat systems (LE3 and LE5) and two-coat systems (LN3 and LN5).

- Measurement variability for the reinforced coatings was larger than that for the liquid coatings, representing from 20% to 39% of the mean. Again, this variability of 8 to 25 mils was probably more associated with panel preparation differences rather than measurement errors.

- Differences between the replicate reinforced products (i.e., two different samples of the same encapsulant product) were on the order of 0.6 mils, and were approximately the same as differences found between replicate liquid products.

Additional analysis of the system thickness data was performed with multiple pairwise comparisons of the product means (Table 14). In this analysis the product means were ordered from highest to lowest and then successive pairs of means were examined for significant differences. These results for dry

Table 14. Results of Multiple Pairwise Comparisons for Dry Film Thickness and Tape Adhesion Testing

Test Type	Liquid Products												Reinforced Products					
Dry Film Thickness-- All Panels--CAE																		
Product	LN5*	LN6	LN3*	LE3*	LE5*	LE1	LN1	LE4	HPI	LPI	LPE	HPE	RE1	RE2*	RE3*	RN2*	RN1*	RN3
Mean (mils)	11.5	11.5	11.1	6.7	6.0	5.9	5.9	5.7	5.6	5.6	5.6	5.5	256.1	21.9	21.5	19.0	18.6	14.0
Group A	A	A											A					
Group B			B											B	B	B	B	B
Group C				C														
Group D					D	D	D	D	D	D	D	D						
Dry Film Thickness-- All Panels--PSI																		
Product	LN5*	LN6	LN3*	LPI	LE1	LE4	HPI	LN1	LE3*	LE5*	HPE	LPE	RE1	RN1*	RE2*	RN2*	RE3*	RN3
Mean (mils)	12.5	12.1	11.6	7.3	7.1	6.9	6.6	6.5	6.1	5.9	5.8	5.3	121.3	20.2	19.4	19.3	18.8	16.4
Group A	A	A											A					
Group B		B	B											B	B	B	B	B
Group C				C	C	C	C											
Group D					D	D	D	D										
Group E						E	E	E	E									
Group F							F	F	F	F	F							
Group G										G	G	G						
Tape Adhesion-- Unexposed Panels--CAE	No analysis - no variation among replicate tests												Test not run					
Tape Adhesion-- Unexposed Panels--PSI																		
Product	LE1	LE4	LE3*	LN6	LN3*	LN5*	HPI	LN1	HPE	LPE	LE5*	LPI	Test not run					
Mean (0-5 rating)	5	5	5	5	5	5	5	5	4	0	0	0						
Group A	A	A	A	A	A	A	A	A										
Group B							B	B	B									
Group C										C	C	C						
Tape Adhesion-- Immersed Panels--CAE	No analysis - no variation among replicate tests												Test not run					
Tape Adhesion-- Immersed Panels--PSI	No analysis - no variation among replicate tests												Test not run					
Tape Adhesion-- Weathered Panels--CAE	No analysis - no variation among replicate tests												Test not run					
Tape Adhesion-- Weathered Panels--PSI	No analysis - no variation among replicate tests												Test not run					

film thickness themselves are not directly relevant to performance testing, but they do help confirm which products can be placed together into similar groups based on their target film thickness:

- The one-coat liquid products (Group D) had mean system thicknesses in the range from 5.5 to 6.0 mils; while the two-coat products (LN5, LN6, and LN3) were twice as thick, being in the range from 11.1 to 11.5 mils.
- The reinforced products (Group B) had mean thicknesses which fell in a broad but similar range from 14.0 to 21.9 mils, with the notable exception of product RE1 (the trowel-applied cementitious product) which had a mean thickness of 256.1 mils.

4.4 TAPE ADHESION

Adhesion is considered a critical property for encapsulants for leaded paint and was therefore evaluated by two different ASTM protocols, the first being the tape adhesion test (ASTM D 3359). Adhesion was determined for twelve exterior and interior liquid products on unexposed panels, water immersed panels, and weathered panels. Reinforced products were not tested using this method. Test Method A (X-cut) was selected over Method B (lattice-cut) which is not easily adaptable to thick, hard test substances. The specified X-cut was made through the product system to the panel surface. Permacel 99 tape was then applied over the X-cut and removed. Adhesion was assessed qualitatively based on how much test material was removed with the tape. The rating scale is 0 (removal of test material beyond the X-cut) to 5 (no peeling or removal).

The tape adhesion test has known limitations, as do many of the traditional adhesion tests for coatings. This adhesion test applies peel stress to the coating so results may not be comparable to adhesion tests that apply tensile or perpendicular forces. In assessing coatings, both of these forces can be factors in adhesion failure.

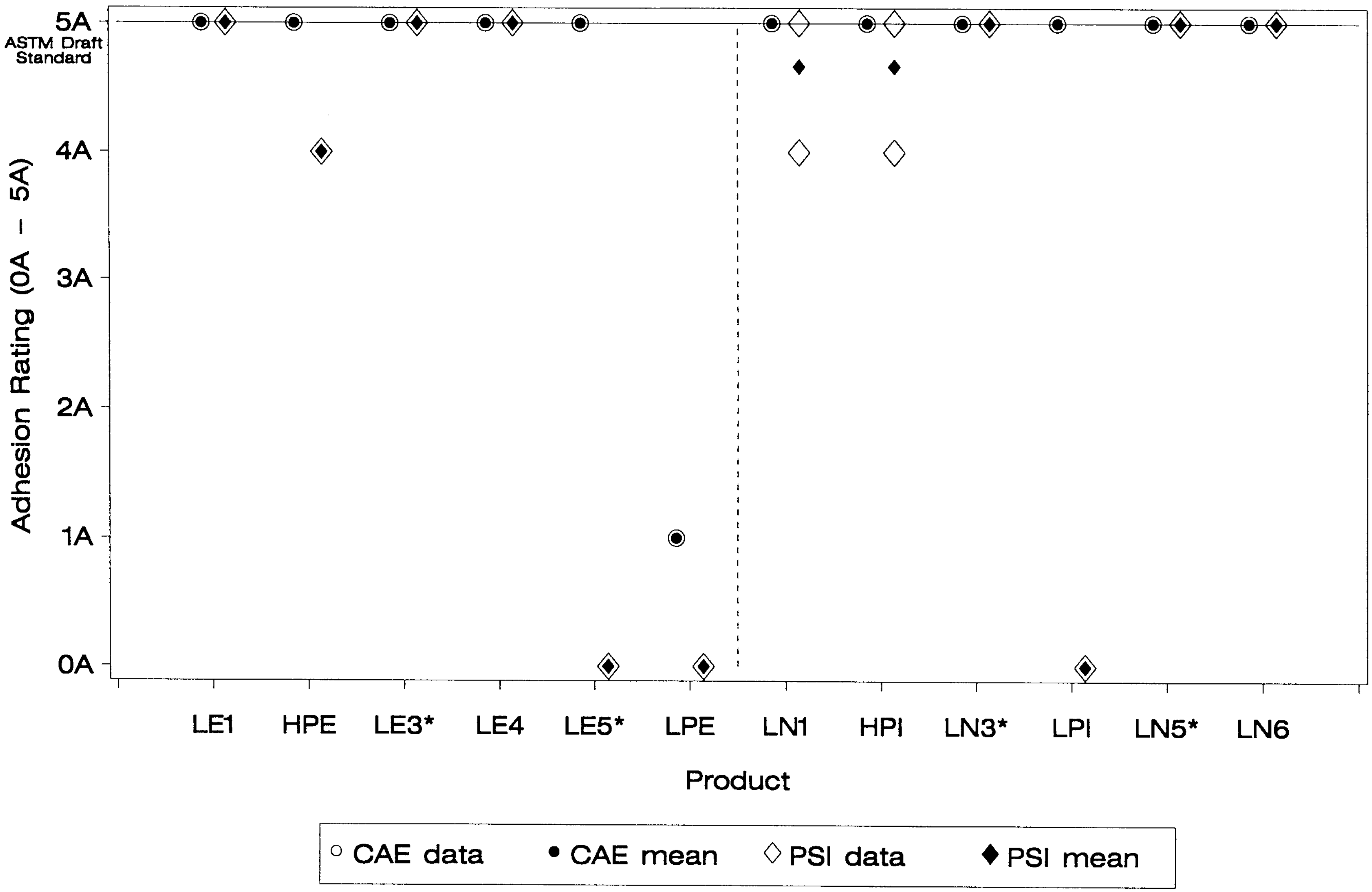
According to ASTM, this test is used to verify "adequate adhesion of a coating to a metal substrate." The limited sensitivity of this test to small differences in adhesion is reflected in the 0 to 5 rating scale specified by the test method. This test is affected by the type and quality of the tape (varies from one lot to another), the pressure used to apply the tape, and the surface characteristics of the coating. Also, operator bias is hard to avoid in test area selection. One operator may test the panel on areas appearing to be adhered. Another might select areas of visibly poor adhesion such as blisters. Ratings from these areas could be quite different even on the same test panel. The test is not usable on reinforced products because it is difficult to score very hard or multi-layer products without producing film damage that can reduce adhesion. For a more complete discussion of the limitations of this adhesion test the reader is referred to the 1994 Annual Book of Standards Volume 6.01 page 435-437.

Unexposed Panels

The tape adhesion results for unexposed panels are shown in Figure 2 for all twelve liquid products tested at both laboratories. The individual test results are shown in the figure along with the mean adhesion by product and laboratory. Also shown in the figure is the ASTM E06.23.30 draft performance standard of 5A for liquid coatings, that is, no loss of adhesion. There were two cases where PSI was unable to complete the adhesion test (Table 11). For the low quality interior paint (LPI) the initial adhesion test removed so much product from the panel that the second and third replicate tests could not be run. Compared to most other products tested, the low-quality exterior

paint (LPE) showed poorer adhesion on the tape adhesion tests at both CAE and PSI.

Figure 2
Tape Adhesion Results for Unexposed Panels



In most cases the adhesion was rated as either 4A or 5A, indicating good adhesion. However, two notable exceptions were found. First, both the exterior and interior low-quality paints showed significant lack of adhesion in some cases, although for the interior paint (LPI) this lack of adhesion was observed at only one laboratory (PSI). And second, one of the acrylic latex exterior encapsulants (LE5) showed a lack of adhesion, although again this result was only observed at one laboratory (PSI), and it was not reproduced for the matching replicate product (LE3). These two cases illustrate the limitations noted above regarding the sensitivity and reproducibility of this test. That is, this test can be affected by tape and adhesive quality, and by operator technique. Operator techniques include how fast the cut is made, how firmly and evenly tape is applied, and how fast and at what angle tape is removed. A detailed discussion can be found in the previously cited Vol. 6.01, p. 436 of the 1994 Annual Book of ASTM Standards.

Additional findings that are indicated from the statistical analyses presented in Tables 13 and 14 are as follows:

- Of the 12 products tested at CAE, all replicate tests for 11 products achieved the draft ASTM E06.23.30 standard of 5A, with the only exception being the low-quality exterior paint (LPE). In testing at PSI, 5A results were consistently achieved by only 6 of the 12 products, and the paints accounted for 4 of the 6 products that did not achieve uniform 5A results.

- There was no measurement variability (i.e., variability among replicate tests) at one laboratory (CAE), and low measurement variability (5% of the mean) at the other laboratory (PSI). This lack of variability is probably tied to the fact that replicate tests were all performed on the same panel. Also, the lack of variability of CAE test results precluded further assessment of statistical significance in those data.

- Significant differences were found in the adhesion test results for replicate encapsulants at PSI, with this finding being driven by the dramatically different results for exterior products LE3 (all tests rated 5A) and LE5 (all tests rated 0A).

- The average adhesion rating at PSI for encapsulants was 2 units higher than the average for paints, and for all four paints at least one test result showed some lack of adhesion (i.e., a rating less than 5A), although for products HPE and HPI these results were simply a 4A (Figure 2).

- The multiple comparison analysis on PSI indicated that the tape adhesion test could distinguish the products into three groups with one distinct set (Group C), consisting of the low-quality paints and encapsulant LE5, showing relatively poor adhesion.

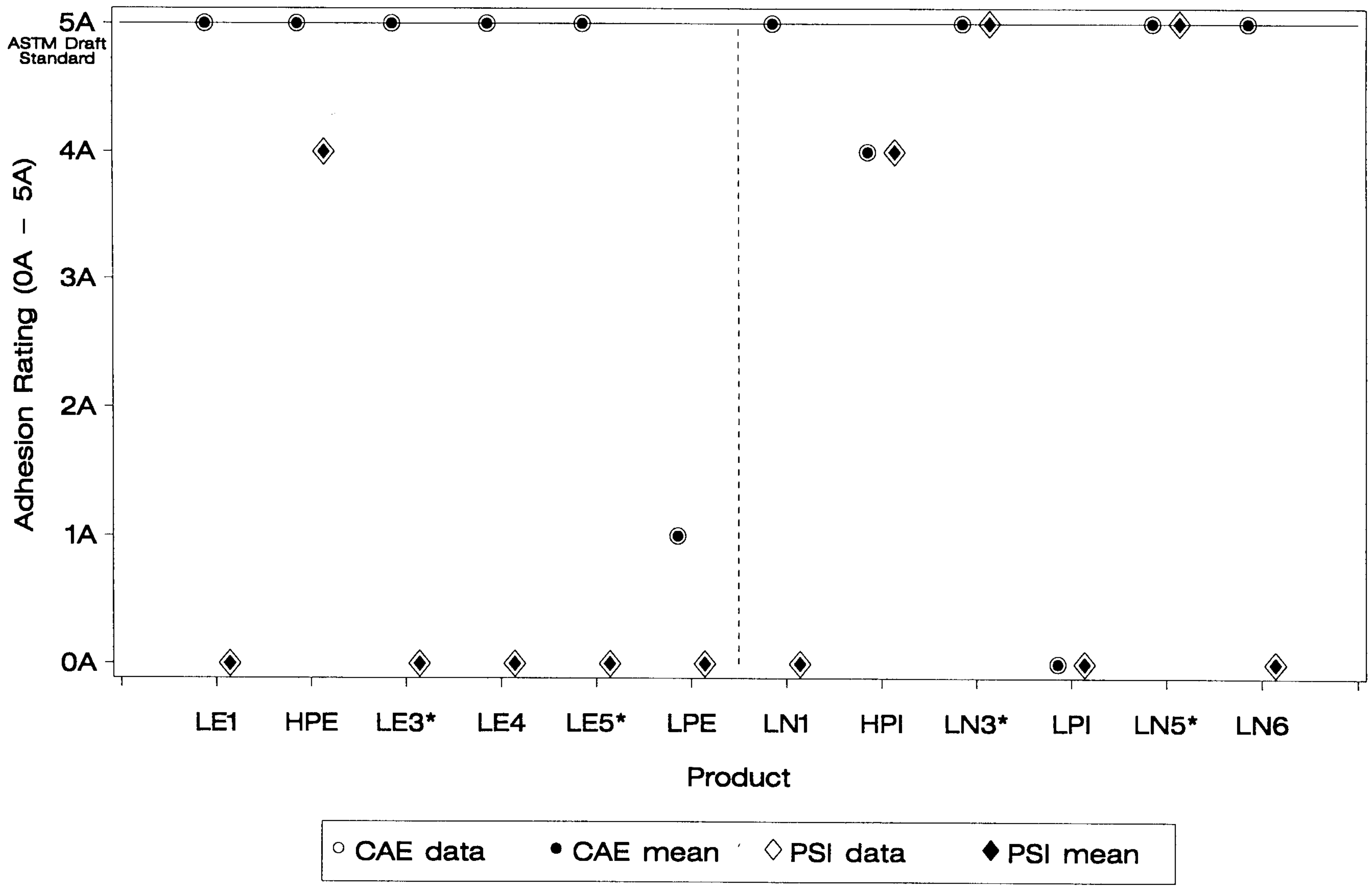
- Because of the lack of measurement variability for CAE results, the multiple pairwise comparisons analysis could not be performed.

Immersed Panels

The tape adhesion results for panels that had been immersed for 24 hours in distilled water are presented in Figure 3. All tests were run approximately 10-20 minutes after removing the panels from the water, and all data were successfully reported (Table 11). The plan was to test tape-adhesion, blistering, and pencil hardness after water immersion all on the same panel. However, while PSI successfully followed this plan, CAE used separate panels to perform the tape-adhesion test than they used for the blistering and pencil hardness tests. This change may have introduced additional laboratory variability to the tape-adhesion results.

In this case testing at CAE showed little loss of adhesion, except for the low-quality paints (LPE and LPI). Interestingly, testing at PSI showed very different results, with significant loss of adhesion for both the low-quality paints and several of the encapsulant products. At PSI only the two high-quality paints and the interior waterborne acrylic encapsulant with primer (replicate products LN3 and LN5) demonstrated adequate

Figure 3
Tape Adhesion Results for Immersed Panels



adhesion after immersion. This difference in results may in part be due to the different protocols used at CAE and PSI, and it may be due to the fact that this test can be highly variable. Additional statistical results shown in Tables 13 and 14 are as follows:

- Of the 12 products tested at CAE, 10 products achieved the draft ASTM E06.23.30 standard of 5A for all replicate tests, with the exception of both low-quality paints. In contrast, testing at PSI indicated only 2 products (the liquid interior waterborne acrylic encapsulants with primer, LN3 and LN5) which achieved uniform 5A results.

- As shown in Table 13, the average adhesion rating for all liquid products measured at CAE (4) was higher than that measured at PSI (2).

- There was no measurement variability observed among replicate tests at either laboratory, precluding further assessment of statistical significance.

- No differences were observed between adhesion ratings for the exterior and interior replicate encapsulants.

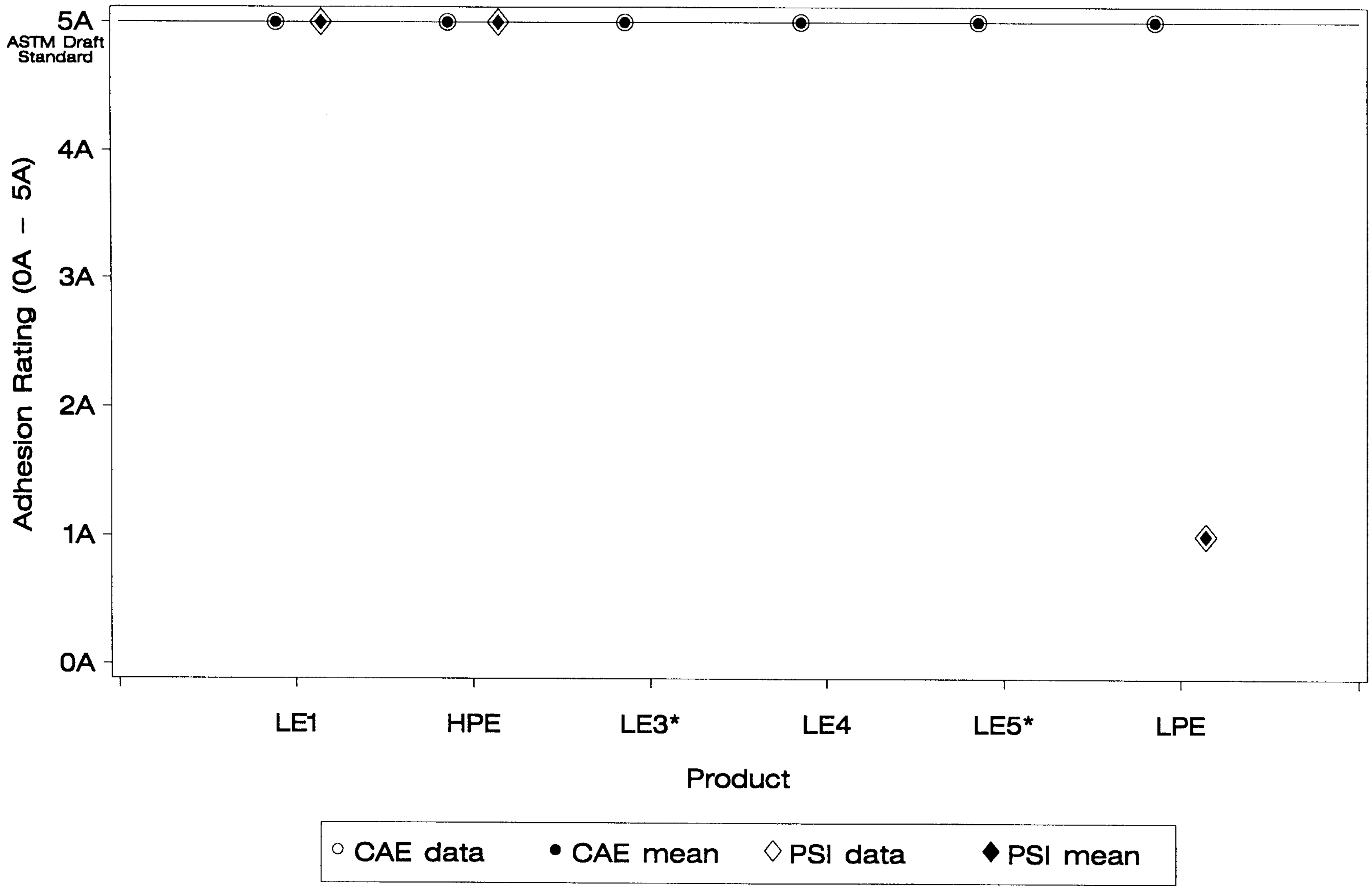
- The average adhesion rating for encapsulants was higher than for paints; at CAE the difference was 3 and at PSI the difference was 1.

- Comparing these results for immersed panels with the previous results for unexposed panels, testing at CAE showed a loss in adhesion for only the interior paints (HPI and LPI); while testing at PSI showed a loss in adhesion for several products (LE1, LE3, LE4, LN1, HPI, and LN6).

<u>Weathered Panels</u>

Tape adhesion results for weathered panels are presented in Figure 4. Note that the weathering protocol was performed only on exterior products. All required data were obtained from CAE; however, PSI experienced three cases (products LE3, LE4, and LE5) where the coatings were destroyed during removal from the

Figure 4
Tape Adhesion Results for Weathered Panels



weathering chamber because they stuck to the panel holders. In these cases all three replicate tests could not be performed.

Figure 4 shows that adhesion was good in all but one case where data were available, the low-quality exterior paint (LPE) tested by PSI. Statistical results shown in Tables 13 and 14 include the following:

- Of the 6 products tested at CAE and the 3 products tested at PSI, all tests achieved the draft ASTM E06.23.30 standard of 5A with the exception of the low-quality exterior paint (LPE) tested at PSI.
- There was no measurement variability observed among replicate tests at either laboratory, precluding further evaluation of statistical significance.
- No difference was observed between the adhesion ratings for the exterior replicate encapsulants.
- At PSI the average adhesion rating for encapsulants was 2 units higher than that for paints.
- Comparing these results for weathered panels with the results for unexposed panels, testing at CAE showed improved adhesion for the low-quality paint (LPE); and testing at PSI showed improved adhesion for both exterior paints (HPE and LPE).

Summary of Tape Adhesion Results

For unexposed panels the variability between replicate products and between the two laboratories was large. For water immersed and weathered panels the between-laboratory variability was large. There is some indication that the tape adhesion test may be able to distinguish between some encapsulants and paints. In several cases when lower adhesion was observed, it was observed for some of the paints. Unfortunately, the results were also often more variable than desired in a reliable test. For example, the results for immersed panels were dramatically different between the two laboratories, and for unexposed panels the results within a single laboratory (PSI) were very different for two replicate encapsulants (LE3 and LE5).

4.5 PULL ADHESION

The second adhesion protocol run in this pilot testing program was ASTM D 4541 for pull adhesion. In this case adhesion was determined for all 18 products on unexposed panels, immersed panels, and weathered panels. This protocol uses a portable test instrument to measure tensile or perpendicular pull strength required to pull a plug of the test substrate from a test panel. A standard metal dolly was first adhered perpendicular to the test substrate surface with a specified epoxy adhesive, and then a pull force was applied to the dolly. The end point was specified as the greatest force that the test coating could resist without loss of adhesion. Alternatively, the test method allows for the end point to be specified before testing begins, in which case the product is tested at the end point and rated pass/fail. To gather the maximum information in this study, the greatest force that each test coating could resist without loss of adhesion was reported. Loss of adhesion could occur along several planes, and so the laboratories also reported the type of failure which occurred. Failures within a product were termed "cohesive failures," while failures between the product and the test panel were "adhesive" failures. Failures between the dolly and the epoxy or between the epoxy and the product were failures of the dolly adhesive itself.

ASTM has not yet provided precision and bias statements for ASTM D 4541. Independent studies have suggested that results in this test vary from one instrument type to another even with adequate calibration of the test instrument. For comparing products of differing thicknesses at different times in different laboratories, it might be more useful to specify that products be tested pass/fail at some specified stress, such as 100 psi, on a particular type of adhesion pull tester.

Also, test panels should be selected that are rigid enough to resist deformation at the pull strengths higher than those of the products being tested. The 0.01 inch tin-plated panel was too thin for satisfactory performance on this test. A thicker steel panel would be a better choice.

Instrumentation

There are several types of adhesion pull testers in use and some evidence suggests that results of the pull test can differ from one type of instrument to another for the same coating sample. In this study, PSI used the Elcometer Adhesion Tester Model 106/1, while CAE used the Model 106/4. The Elcometer uses a spring arrangement to apply a force to the dolly. The force to remove the dolly is indicated on the instrument scale as stress (i.e., force per unit area) measured in pounds per square inch (psi). Other well known types of adhesion pull testers include the Patti pneumatic adhesion tester and the Hate hydraulic adhesion tester. In some laboratories pull testing is accomplished by modification of tensile testers such as an Instron or Tinius tensile tester.

The selection of the appropriate Elcometer scale should be based on the expected pull-off stress of the samples to be tested. The Model 106/1 scale is most appropriate for stresses between 100-500 psi, while the Model 106/4 scale is most appropriate for stresses between 500 to 4000 psi. (100 psi is approximately equal to 0.69 MPa.) In this study the range of pull-off stresses was concentrated from 100 to 500 psi, so the Elcometer 106/1 scale was most appropriate. The Elcometer 106/4 scale does allow interpolation for results less than 500 psi, but these interpolated results may have limited accuracy.

Dolly Adhesion

A two-part epoxy, 3M 1838, was used to secure the dollies to all products. This adhesive reaches full strength at room temperature in 24 hours. The required 24-hour cure time presented a dilemma for adhering dollies for the post-water immersion testing. Adhesion was to be tested immediately (10 minutes) after immersion and again after a two-hour recovery period. One option was to adhere the dollies to the test panels prior to water immersion to allow the adhesive to reach full strength before immersion. However, the product under the dolly would then be somewhat protected from exposure to the water, and the pull adhesion results might not be representative of adhesion in a totally exposed area. The second option was to adhere the dollies to the product surface after removal from the water immersion. In this case, the 24-hour cure time needed to reach full adhesive dolly strength prevented testing 10 minutes and two hours after immersion since the dollies might not have adequate adhesive strength.

The plan was to adhere the dollies after immersion. PSI began the test and discovered that the adhesive would not cure rapidly enough to allow testing 10 minutes or 120 minutes after immersion. Based on this experience, the other laboratory, CAE, proceeding with this test a few days later, was instructed to adhere the dollies before immersion so that pull testing could be accomplished at 10 and 120 minutes after immersion.

The 0.01 inch tin-plated steel test panels specified for this test were not rigid enough to resist deformation due to the stress exerted by the test apparatus. Therefore, a second uncoated panel had to be adhered to the back of each already prepared test panel to prevent deformation during pull testing. The same two-part epoxy that was used to adhere dollies was also used to secure these extra panels.

In several cases during testing in this study, the dolly epoxy did not adhere well to the test substrate and failure occurred between the epoxy and the coating during, or prior to, mounting in the test instrument. There was no attempt made to optimize the dolly adhesive for individual products in this study. That is, although the products represented a variety of chemical types, all dollies were fastened with the same adhesive, and it is possible that the selected adhesive was inadequate for some products. There were also some instances of loss of adhesion between the test dolly and the selected epoxy. These failures could have been due to factors such as improper preparation of the dolly surface, inadequate mixing of the adhesive, or choice of an adhesive that adhered more strongly to some test coatings than to the test dollies.

Scoring Around the Dolly

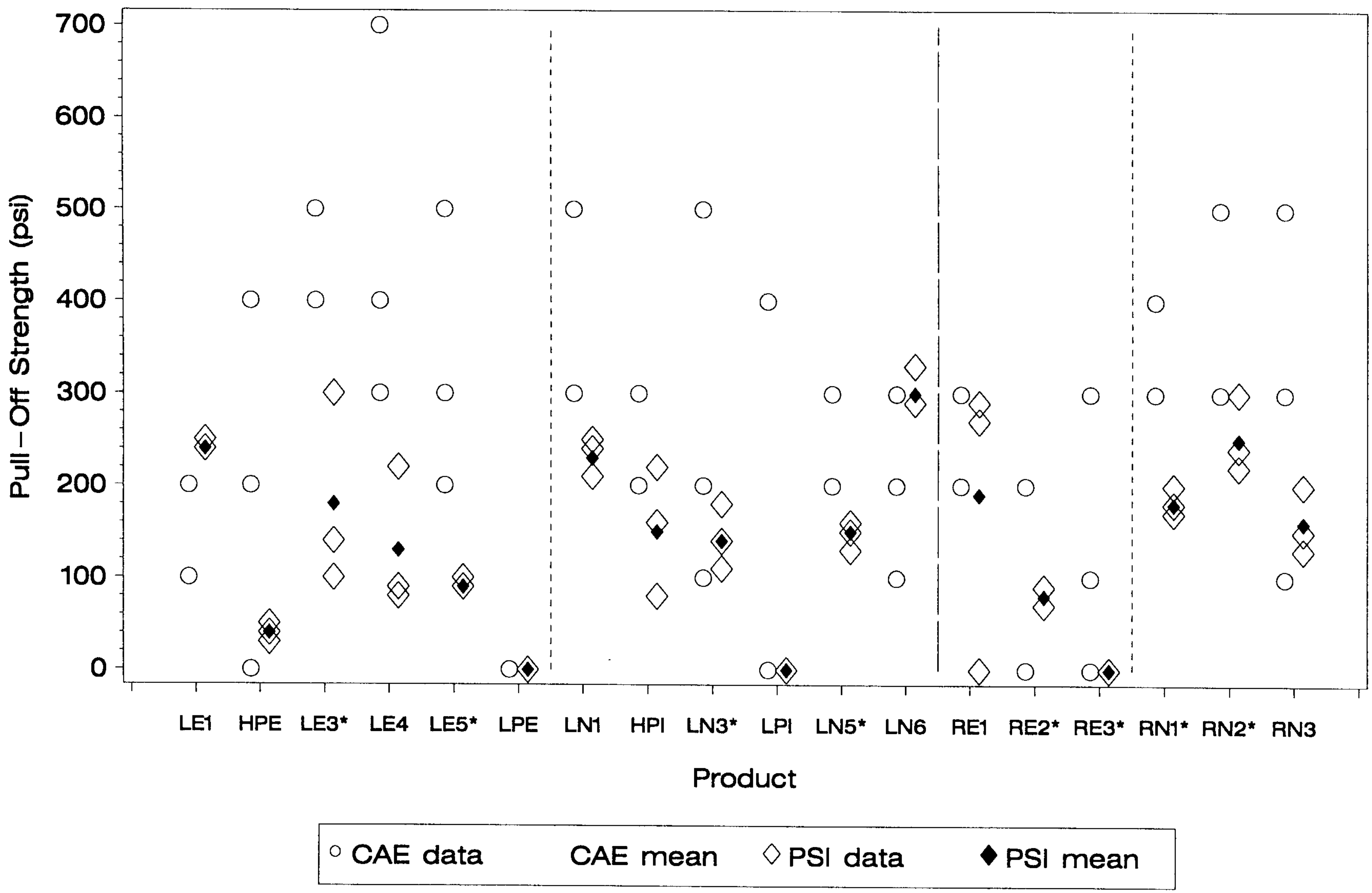
This pull test is usually run without scoring around the dollies. In this study, the test area was scored after dolly placement so that the pull was not against the reinforcing material. If the load is spread across the panel, then mat area and test panel area can become factors in the force required to remove the dolly from the test panel. If no scoring is used on reinforced materials, pull is spread across the reinforcing mat. However, several of the reinforced products were very difficult to cut through to the test panel and scoring could have produced stress in the film that reduced adhesion. Scoring is not the recommended procedure in the test method; however, it is a permitted option.

Results for Unexposed Panels

The pull adhesion results for unexposed panels are presented in Figure 5 for all 18 products and both testing laboratories. As shown earlier in Table 11, there were three cases where PSI

was unable to conduct the pull adhesion test. In all three cases (one RE2 panel and two RE3 panels), PSI experienced a dolly epoxy failure during scoring or placement into the adhesion tester, and before testing could be initiated. There were also eight cases (two LE4 panels, one LN3 panel, three LN6 panels, and two RN3 panels) where CAE experienced dolly epoxy failures, but they occurred during testing so that a pull-off strength could be recorded. In these cases the recorded data represent lower limits for the pull-off strength of the coating being tested. In

Figure 5
Pull Adhesion Results for Unexposed Panels



addition, there were eight cases at PSI (three LPE panels, three LPI panels, one RE1 panel and one RE3 panel) and nine cases at CAE (one HPE panel, three LPE panels, two LPI panels, two RE2 panels, and two RE3 panels) where the coatings separated from the panels at a very low pull-off strength (essentially 0 psi).

It should be noted in Figure 5 that because of the two different instruments used by the two laboratories for testing, CAE and PSI reported data with different accuracy for the pull adhesion test. CAE reported data to the nearest 100 psi, while PSI reported data to the nearest 10 psi. The results shown in Figure 5 indicate rather variable pull-off strengths ranging from a minimum near 0 psi to a maximum of 700 psi. This variability is further quantified by the statistical results listed in Tables 12, 13, and 15, which can be summarized as follows:

- No draft ASTM E06.23.30 standard is available for comparison because ASTM is no longer planning to use the pull adhesion test in their protocol.

- Pull-off strength was similar for the liquid and reinforced coatings, averaging 200 psi in both cases (Table 12). However, the 300 psi average pull-off strength measured by CAE was higher than the 140 psi average pull-off strength measured by PSI (Table 13). As noted in Section 3.2, such laboratory differences were only qualitatively evaluated, rather than tested for statistical significance. It is not clear whether in this case the difference is due to the difference in instrumentation used for testing, or to unknown factors related to panel preparation, although the former reason is probably most likely the case.

- Measurement variability among replicate test panels was reasonably high, ranging from 32% to 47% of the mean for the two laboratories (Table 13).

- Differences between test results for replicate products were not found to be significant (Table 13).

- The pull-off strength of liquid encapsulants was found by both laboratories to be significantly greater than the pull-off strength of paints (Table 13). The difference

was estimated by CAE to be 200 psi, and by PSI to be 150 psi.

- **For the liquid coatings a number of overlapping groups were identified by the multiple comparisons analysis with the lowest pull-off strengths at both CAE and PSI being generally found for the paints (e.g., PSI Group E). However, the pull adhesion test could not distinguish groups of similar products among the reinforced coatings (Table 15).**

Immersed Panels

Pull adhesion data for the immersed panels are presented in Figures 6 and 7, corresponding to readings taken approximately 10-20 minutes and 120 minutes after immersion, respectively. Two replicate panels were planned for the 10-minute dry, while only one panel was to be evaluated after the 120-minute dry. As shown in Table 11 and discussed above, there was a great deal of difficulty conducting the pull test after immersion because of problems fastening the dollies to the coatings. PSI, which tried to fasten the dollies after panel immersion, had no success running the test, and no measured data were reported. CAE on the other hand, which fastened the dollies before panel immersion, was able to conduct most of the tests and report 49 of 54 planned results. However, the CAE results may not accurately represent 24-hour water immersion since the presence of the pre-attached dolly could protect the product system directly underneath the dolly. Pull adhesion data for these immersed panels could be artificially high. Four of the CAE cases which could not be tested (one panel each for LPE and LPI, and two RE1 panels) were due to dolly epoxy failures during scoring or loading into the test apparatus, while the fifth CAE case (one RE3 panel) was due to loss of adhesion between product and panel before immersion.

The following points summarize the results of the post-immersion pull adhesion testing which are listed in Figures 6 and 7, as well as Tables 12, 13, and 15:

- **For the liquid coatings, CAE pull-off strengths 10 minutes after immersion were lower (averaging 200 psi) than pull-off strengths for unexposed panels (averaging**

Table 15. Results of Multiple Pairwise Comparisons for Pull Adhesion Testing

Test Type	Liquid Products												Reinforced Products					
Pull Adhesion-- Unexposed Panels--CAE																		
Product	LE3*	LE4	LN1	LE5*	LN3*	LN5*	HPI	HPE	LN6	LE1	LPI	LPE	RN2*	RN1*	RN3	RE1	RE3*	RE2*
Mean (psi)	500	500	400	300	300	300	200	200	200	200	100	0	400	300	300	300	100	100
Group A	A	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A
Group B				B	B	B	B	B	B	B	B	B						
Pull Adhesion-- Unexposed Panels--PSI																		
Product	LN6	LE1	LN1	LE3*	HPI	LN5*	LN3*	LE4	LE5*	HPE	LPE	LPI	RN2*	RE1	RN1*	RN3	RE2*	RE3*
Mean (psi)	300	240	230	180	150	150	140	130	90	40	0	0	250	190	180	160	80	0
Group A	A	A	A	A									A	A	A	A	A	A
Group B			B	B	B	B	B	B										
Group C				C	C	C	C	C	C									
Group D					D	D	D	D	D	D								
Group E								E	E	E	E	E						
Pull Adhesion--10 min. After Immersion--CAE																		
Product	LN1	LN6	LN3*	LN5*	LE3*	LE4	LE5*	LE1	HPI	HPE	LPE	LPI	RN3	RE3*	RE2*	RN1*	RN2*	RE1
Mean (psi)	500	300	300	300	300	200	200	200	200	100	0	0	500	300	300	200	200	0
Group A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Pull Adhesion--10 min. After Immersion--PSI	No data available												No data available					
Pull Adhesion--120 min After Immersion--CAE	No analysis--only one panel per product												No analysis--only one panel per product					
Pull Adhesion--120 min. After Immersion--PSI	No data available												No data available					
Pull Adhesion-- Weathered Panels--CAE																		
Product	LE3*	LE5*	LE1	LE4	HPE	LPE							No analysis--no variation among panels					
Mean (psi)	500	400	300	300	200	0												
Group A	A	A	A	A	A													
Group B		B	B	B	B	B												
Pull Adhesion-- Weathered Panels--PSI																		
Product	LE5*	LE1	LE3*	LE4	HPE	LPE							RE1	RE2*	RE3*			
Mean (psi)	270	250	220	150	120	0							240	10	10			
Group A	A	A	A	A									A					
Group B		B	B	B	B									B	B			
Group C				C	C	C												

::

Figure 6
Pull Adhesion Results for Immersed (10 minute dry) Panels

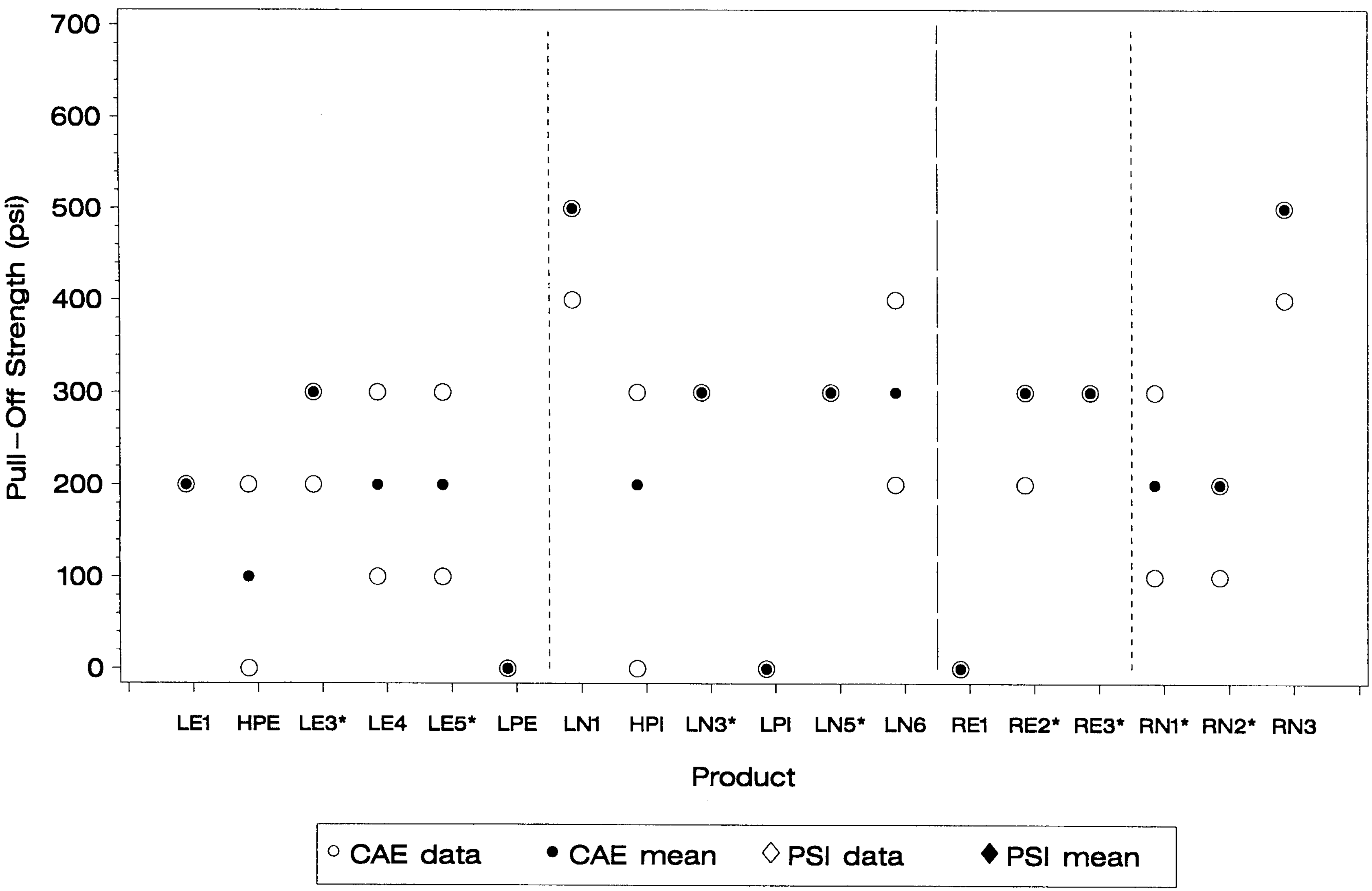
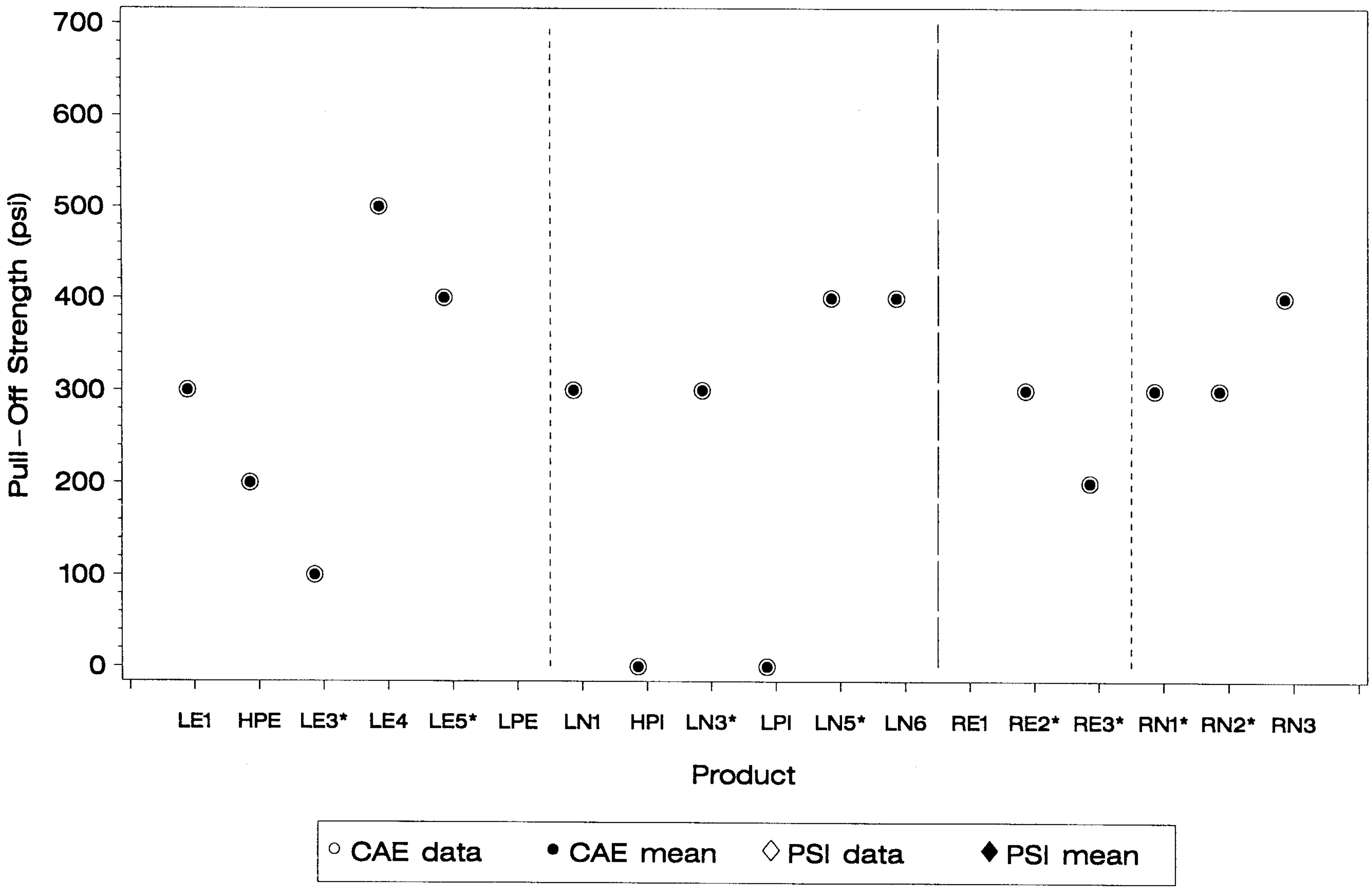


Figure 7
Pull Adhesion Results for Immersed (120 minute dry) Panels



300 psi). However, 120 minutes after immersion the pull-off strengths recovered to readings (averaging 300 psi) similar to those for unexposed panels.

- **Measurement variability 10 minutes after immersion was found to be 56% and 47% of the mean for liquid and reinforced coatings, respectively, which was generally equivalent to the variability found for unexposed panels. No estimate of measurement variability 120 minutes after immersion could be made since only one panel per product was tested.**

- **Differences in pull-off strengths after immersion between replicate products were sometimes large, ranging from 0 psi to 300 psi; however, none of these differences could be judged to be statistically significant.**

- **Pull-off strength after immersion was again found to be greater for liquid encapsulants than for paints (Table 13). Ten minutes post immersion this difference was statistically significant and found to be 200 psi; while 120 minutes post immersion the difference was found to be 300 psi, although in the latter case the statistical significance of the difference could not be assessed since no estimate of measurement variability could be made.**

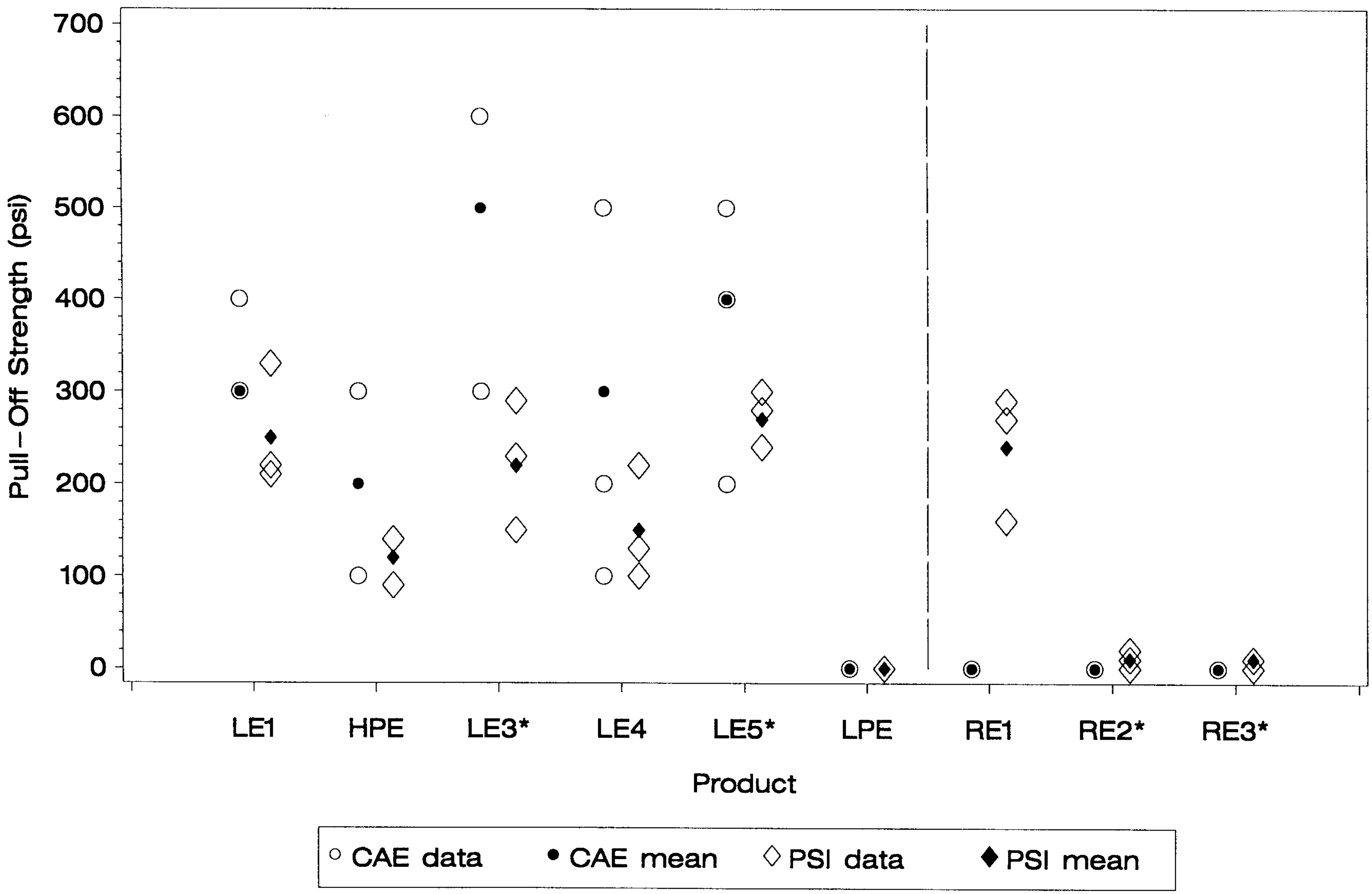
- **The multiple pairwise comparisons analysis could only be performed for CAE test results run 10 minutes after immersion; however, even in this case no significant groupings among the products could be distinguished by the pull adhesion test (Table 15).**

Weathered Panels

Pull adhesion results for the weathered panels are shown in Figure 8. Three replicate panels were planned for each of the nine exterior products. As shown in Table 11, all planned data were collected with three exceptions. Two CAE panels (both RE1 product), as well as one PSI panel (product HPE), could not be tested due to dolly epoxy failures during scoring or loading into the test apparatus.

Analysis of the weathered pull adhesion data is summarized in Tables 12, 13, and 15, and highlighted by the following points:

Figure 8
Pull Adhesion Results for Weathered Panels



- For liquid coatings pull-off strength after weathering was the same (averaging 200 psi) as that for unexposed panels. However, for reinforced coatings this was not true; pull-off strength after weathering was lower (0 psi) than that for unexposed panels (200 psi). The decrease in adhesion after weathering could have a number of explanations including, but not limited to, coating degradation, different rates of thermal expansion for different reinforcing mats, panels etc. Because of the variables, a more detailed study would be necessary to determine the cause or causes.

- Test results measured at CAE for weathered panels were consistently higher than those measured at PSI, probably due to the different instruments used for testing.

- Measurement variability for the weathered panels was consistent with that observed for both the unexposed and immersed pull adhesion tests, ranging from 31% to 46% of the mean for the two laboratories.

- Differences between replicate encapsulant products were not found to be statistically significant.

- Post-weathering pull adhesion for liquid products was generally greater than that for reinforced products.

- Pull-off strength after weathering for the exterior liquid encapsulants was again found to be significantly higher than that for standard exterior paints. CAE estimated the difference to be 200 psi, while PSI estimated the difference at 160 psi.

- Multiple comparisons results for the exterior liquid coatings indicated that the pull adhesion test distinguished either two (CAE) or three (PSI) overlapping groups, with pull adhesion for the paints and encapsulant product LE4 (e.g., PSI Group C in Table 15) generally falling below that of the other exterior encapsulants. For the exterior reinforced products tested at PSI, the weathered pull adhesion test distinguished the cementitious product RE1 from the other two products.

Summary of Pull Adhesion Results

The pull adhesion protocol is a more quantitative test than the tape adhesion protocol, and results from this study indicate that it may be able to distinguish among some products.

Instrumentation appears to be an important factor because the results obtained by PSI with the Elcometer Model 106/1 were consistently higher than those obtained by CAE with the Elcometer Model 106/4. The scale used by CAE required the data to be measured to the nearest 100 psi, while the data for PSI were measured to the nearest 10 psi. Adhesion to the tin-plated steel panels used in this test was a problem for some coatings; there were several cases where the measured adhesion was near 0 psi. It is also interesting to note that pull adhesion was generally equivalent for the liquid and reinforced products, except after weathering, where the pull adhesion of liquid products was greater than that of reinforced products.

Selecting an adhesive for fastening dollies to the coatings was important, particularly when the pull adhesion protocol was run in conjunction with water immersion testing. Testing at PSI found that fastening the dollies soon after immersion was not a viable option for testing less than 24 hours after immersion. Also, fastening the dollies before immersion may interfere with the water/product interaction. However, based on CAE data where the dollies were fastened before immersion, post-immersion pull adhesion was generally lower 10 minutes after immersion than that for unexposed panels, while adhesion was generally restored 120 minutes after immersion to the levels of unexposed panels.

For unexposed panels both laboratory variability and measurement variability were high. For water immersed panels both replicate product variability and measurement variability were high; and the multiple comparisons analysis could distinguish no clear groupings among the products. For weathered panels both laboratory variability and measurement variability were high.

4.6 SCRUB RESISTANCE

Scrub resistance was measured for all 18 products on unexposed panels and for the nine exterior products after weathering. This ASTM test is primarily designed for evaluation of interior paints and its use in conjunction with the 1000 hour weathering cycle presented two technical challenges associated with the panel size and panel composition. First, the black plastic panels commercially available for use in this test are sized 165 by 432 by 0.25 mm (6½ by 17 inches by 10 mils) to fit the washability test instruments. However, the sample panel holders in the QUV test chambers accommodate samples only 89 by 305 mm (3½ by 12 inches) long. Therefore, procedural modifications had to be devised to allow scrub testing weathered samples in this study. The second technical challenge was the polymer composition of the scrub panels supplied by Leneta Company. In this study the panels deformed in the weathering cycle in less than 200 hours, leaving an uneven surface. The type of polymer used to make the Leneta panels is considered proprietary, but the supplier did confirm that the polymer was not selected for resistance to heat. In order to obtain repeatable scrub test results, the sample panel should be level so that the brush can uniformly contact the film surface during testing. Therefore, performing the scrub test on exterior products after a weathering cycle will require a new test panel composition and modification of the holding frame on the commercial washability machines.

Since these products were tested at a variety of thicknesses, the scrub results should be examined for trends only. If the products not reaching 5000 cycles were applied at a greater film thickness, the results could be different. Results from this test would be easier to interpret comparatively if all products had been tested at the same thickness. However, many of these products are specifically formulated for best performance at higher system thicknesses, and panels in this study were prepared according to manufacturer recommendations. Careful consideration should be given to sample panel film thickness when conducting this test in the future.

Also, the test procedure is time consuming to run to failure or 5000 cycles as specified in this study. The method calls for observation of the test substrate and addition of fresh scrub medium every 400 cycles. Therefore, carrying this test to 5000 cycles requires technician intervention at 11 minute intervals for about three hours. Since two (or three) test panels must be scrubbed for each product test, testing to 5000 cycles is labor intensive and time consuming, and provides minimal information. ASTM E06.23.30 requires testing to only 1200 cycles.

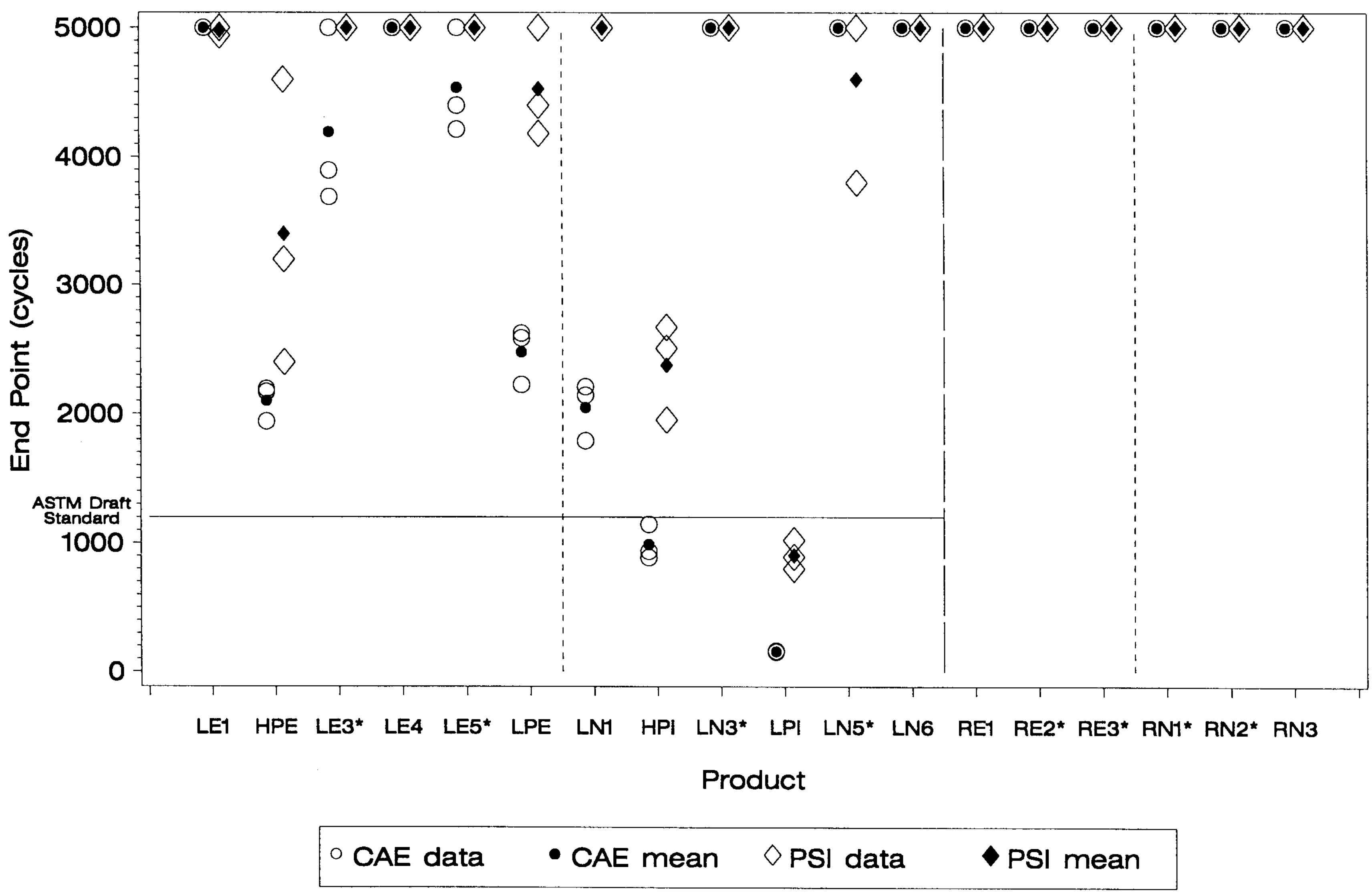
Results for Unexposed Panels

Figure 9 presents the results from running the scrub resistance protocol at both laboratories on unexposed panels coated with all 18 products. This figure is similar to the earlier adhesion figures in that it lists individual test results for each product along with the mean result. Also note that Figure 9 shows as a horizontal line the ASTM E06.23.30 draft performance standard for liquid coatings which is currently proposed at 1200 cycles. Data completeness for this test was quite good (Table 11). However, due to the surface variability sometimes introduced by hand-troweled panel preparation, one panel at CAE could not be tested because the brush would not track properly over the rough surface of the cementitious product RE1.

The results in Figure 9 indicate that several encapsulant systems are durable enough and/or applied at sufficient thickness to survive the scrubbing protocol for a full 5000 cycles. This statement is particularly true for the reinforced products where all six systems lasted the full 5000 cycles without breakthrough. This fact results in censored data for those coatings that last

5000 cycles; that is, the true end point for these coatings is greater than 5000 cycles, but that endpoint can not be observed due to the 5000 cycle constraint placed on the protocol. It should be noted that this censoring has not been formally dealt

Figure 9
Scrub Resistance Results for Unexposed Panels



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with in the statistical analyses which follow. Censoring generally results in underestimates of data variability, which can affect subsequent assessments of statistical significance.

Results of the statistical analyses are presented in Tables 12, 13 and 16, and are summarized as follows:

- Of the 12 liquid products tested at CAE and PSI, all but 3 products achieved scrub resistance results greater than the draft ASTM E06.23.30 standard of 1200 cycles. The high-quality interior paint (HPI) tested at CAE, and the low-quality interior paint (LPI) tested at both CAE and PSI failed to meet the draft ASTM standard. There is currently no draft ASTM standard for reinforced products.

- As noted above, every panel for the reinforced coatings tested at both CAE and PSI lasted the full 5000 cycles, so the test could distinguish no differences between any of the six reinforced products.

- In contrast, there were 11 out of 24 cases where all panels with a liquid coating tested either at CAE or PSI lasted 5000 cycles. The mean end point for all liquid coatings tested on unexposed panels was 3846 cycles. However, it is interesting to note that the mean end point for liquid coatings tested at CAE was 3459 cycles while the mean end point measured by PSI was higher at 4232 cycles.

- Measurement variability among replicate test panels was found to be relatively low for the scrub test, ranging from 7% to 10% of the mean (Table 13). However, as noted above, this variability is probably underestimated due to censoring in the data.

- Variability between the scrub results for replicate encapsulant products was not found to be significant (Table 13). Again, this result may have been affected by data censoring.

- The average end point for liquid encapsulants was found at both laboratories to be significantly greater than the average end point for paints (Table 13). At CAE this difference was estimated to be 2971 cycles, and at PSI the difference was estimated at 2161 cycles.

- **The multiple comparisons analysis could not be performed for the reinforced coatings. For the liquid coatings this analysis showed that the scrub test distinguished 4**

Table 16. Results of Multiple Pairwise Comparisons for Scrub Resistance Testing

Test Type	Liquid Products												Reinforced Products
Scrub Resistance--Unexposed Panels--CAE													
Product	LE1	LE4	LN5*	LN6	LN3*	LE5*	LE3*	LPE	HPE	LN1	HPI	LPI	No analysis--no variation among panels
Mean (cycles)	5000	5000	5000	5000	5000	4538	4195	2479	2100	2048	989	158	
Group A	A	A	A	A	A	A							
Group B						B	B						
Group C								C	C	C			
Group D											D		
Group E												E	
Scrub Resistance--Unexposed Panels--PSI													
Product	LN3*	LE4	LE3*	LN6	LE5*	LN1	LE1	LN5*	LPE	HPE	HPI	LPI	No analysis--no variation among panels
Mean (cycles)	5000	5000	5000	5000	5000	5000	4980	4600	4527	3400	2377	904	
Group A	A	A	A	A	A	A	A	A	A				
Group B								B	B	B			
Group C										C	C		
Group D												D	
Scrub Resistance--Weathered Panels--CAE													
Product	LE5*	LPE	LE3*	LE4	LE1	HPE							No analysis--no variation among panels
Mean (cycles)	5000	5000	5000	5000	4797	4031							
Group A	A	A	A	A	A								
Group B						B							
Scrub Resistance--Weathered Panels--PSI	No analysis - no variation among panels												No analysis--no variation among panels

::

or 5 groups of similar products at PSI and CAE, with the paints and one encapsulant (LN1 at CAE and LN5 at PSI) being grouped together with lower end points (Table 16).

Weathered Panels

Scrub resistance data for the weathered panels are presented in Figure 10. In this case three replicate panels were to be tested for each of the nine exterior products. As discussed earlier, deformation was frequently observed for scrub resistance panels that were subjected to the weathering protocol. Therefore, all of the data in Figure 10 may have been compromised to some degree. And in fact, because of the problems with panel warping, relatively few measured results were obtained from this test protocol at all (Table 11). Five panels at CAE and 17 panels at PSI were too warped to test.

Results from the analysis of these data are shown in Tables 12, 13, and 16, and are summarized in the following points:

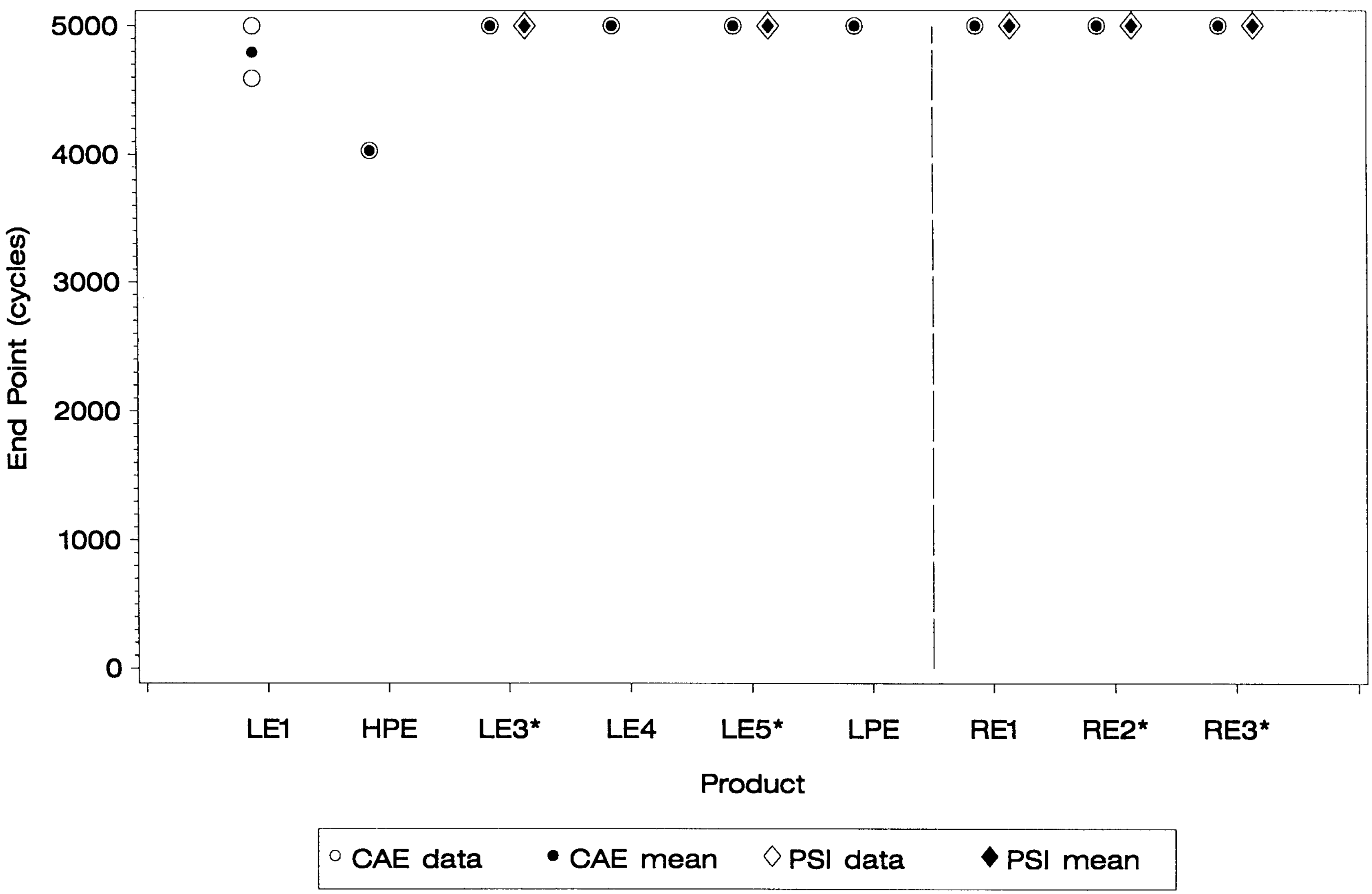
- All test panels lasted at least 4000 cycles (Table 12), and all panels for 7 of the 9 products tested lasted the full 5000 cycles.

- As was the case for unexposed panels, every panel for the three exterior reinforced products lasted the full 5000 cycles. In addition, all panels for four of the six exterior liquid products lasted 5000 cycles. The mean end point for all weathered liquid products tested was 4914 cycles. In addition, all tests run for weathered liquid products at PSI lasted 5000 cycles, while tests run at CAE were essentially the same, averaging a slightly lower 4894 cycles.

- After weathering, scrub resistance was typically equal to or higher than that for unexposed panels. The lone exception to this finding was product LE1 tested at CAE where the average end point after weathering was 4797 cycles as opposed to 5000 cycles for unexposed panels. As a result, the mean end point for all weathered liquid products (4914 cycles) was greater than that for all unexposed liquid products (3846 cycles).

- **Measurement variability for the weathered panels at CAE was estimated at only 2% of the mean. However, as with**

Figure 10
Scrub Resistance Results for Weathered Panels



all the scrub resistance results, this is probably an underestimate due to data censoring.

- No variation was observed for weathered scrub resistance between replicate encapsulant products.

- Just as for unexposed panels, scrub resistance for weathered liquid encapsulants tested at CAE was found to be statistically significantly greater than that for paints (Table 13); however, the estimated difference was only 417 cycles, which is only slightly above the 400 cycle interval at which observations are made, and therefore is of marginal practical significance. This same comparison could not be performed at PSI since no weathered paints could be tested.

- The multiple comparisons analysis showed that the weathered scrub test distinguished only one significant grouping, which was that the weathered scrub resistance for the high-quality paint (HPE) tested at CAE was lower than that for the other liquid products (Table 16).

Summary of Scrub Resistance Results

The results of this study indicate that the scrub resistance protocol may be able to distinguish among some products. The mean end point for unexposed encapsulants was about 2000-3000 cycles greater than the mean end point for unexposed paints. However, it should be remembered that three of the eight encapsulants were two-coat systems which were applied at approximately twice the thickness of the one-coat paints. Furthermore, when comparing the test results against the current draft ASTM standard of 1200 cycles, several of the unexposed products in this study lasted 2000 cycles or more and weathered products lasted even longer (4000 cycles or more). For reinforced encapsulants it is important to note that every tested panel lasted the full 5000 cycles, and therefore the test may be inappropriate for reinforced products since it was unable to distinguish among them. It was also interesting that the mean end point for unexposed liquid coatings tested at PSI was approximately 800 cycles higher than that at CAE; this difference may be an indication of the laboratory variability to be expected with the scrub resistance test.

When performing the scrub test in conjunction with the weathering protocol, it is important to realize that consistent and reliable results are not possible using the standard black plastic panels. This is because serious panel warping during the weathering step was found to occur in many cases, leaving the panels with an uneven surface along which the scrubbing brush could not uniformly pass. However, these study results suggest that resistance for weathered panels can be greater than that for unexposed panels.

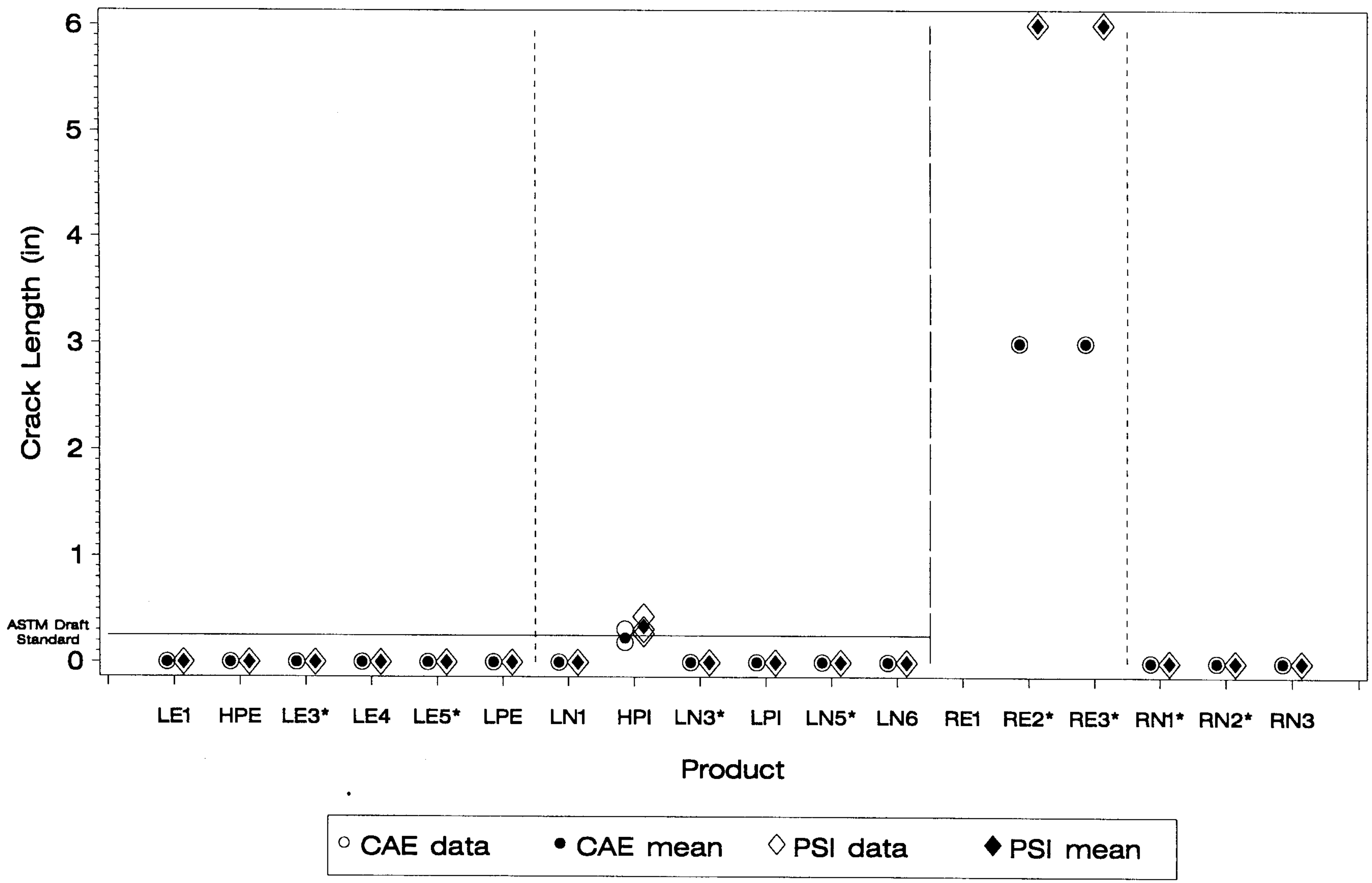
4.7 FLEXIBILITY

Flexibility was determined for all 18 products on unexposed panels and for all nine exterior products after weathering. The test method used in this study specified a five-second bend around a conical mandrel. Crack length was then reported as a measure of resistance to cracking. ASTM considers this test acceptable for evaluating the resistance to cracking of attached coatings. The encapsulant products tested in this study were not formulated specifically for adhesion to unpainted metal surfaces. For example, products RE2 and RE3 represent a polyester/acrylic chemistry that is unlike any of the other encapsulants tested. These products may have quite good adhesion to intended substrates but do not adhere adequately to the metal panels selected for this test so results may not be comparable to other products tested. Also, the trowel-applied RE1 product could not be tested for flexibility using this test because the prepared sample panels were too thick to insert into the conical mandrel test instrument.

Results for Unexposed Panels

The results from running the flexibility test on unexposed panels are shown in Figure 11 for 17 of the 18 products tested.

Figure 11
Flexibility Results for Unexposed Panels



As stated above, the cementitious product RE1 was too thick to fit into the testing apparatus, resulting in three missing tests for each laboratory. Also shown in Figure 11 is the ASTM E06.23.30 draft performance standard for liquid coatings of cracks less than or equal to 0.25 inches. The results in this figure indicate that very few panels experienced cracking during the test, that is, most coatings were reasonably flexible. Also, the results were often identical for all three replicate panels of each product.

The lack of variability in the flexibility test results precluded a sophisticated statistical analysis; however, the findings which could be made are presented in Tables 12, 13, and 17, as well as in the following points:

- Of the 12 liquid products tested at CAE and PSI, all but one product, the high-quality interior paint (HPI) tested at both CAE and PSI, achieved flexibility results below the draft ASTM E06.23.30 standard of a 0.25 inch crack length. There is currently no draft ASTM standard for reinforced products.

- Only three products experienced any cracking whatsoever, the high-quality interior paint (HPI) and the replicate reinforced exterior encapsulant, which was an acrylic and polyester composite with fiberglass non-woven mat (RE2 and RE3). In the case of the reinforced product, the coating cracked along its entire length (i.e., 6 inches for PSI, and 3 inches for CAE who oriented the panels in the opposite direction).

- Because most replicate test panels returned identical, or nearly identical, results, the estimated measurement variability was low, although relative to the mean this variability ranged from 67% to 100% for the two laboratories (Table 13).

- No differences in flexibility were observed for replicate encapsulant products.

- Since the paint HPI was the only liquid product to crack, there was a statistically significant difference between the mean crack length for encapsulants and paints (Table 13); however, no difference was observed for the other paints. Based on CAE data this mean difference was -0.06

inches, while based on PSI data the difference was -0.08 inches.

Table 17. Results of Multiple Pairwise Comparisons for Flexibility and Impact Resistance Testing

Test Type	Liquid Products												Reinforced Products
Flexibility-- Unexposed Panels--CAE													
Product	HPI	LE1	LE3*	HPE	LE5*	LPE	LN1	LE4	LN3*	LPI	LN5*	LN6	No analysis--no variation among panels
Mean (crack length in.)	0.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Group A	A												
Group B		B	B	B	B	B	B	B	B	B	B	B	
Flexibility-- Unexposed Panels--PSI													
Product	HPI	LE1	LE3*	HPE	LE5*	LPE	LN1	LE4	LN3*	LPI	LN5*	LN6	No analysis--no variation among panels
Mean (crack length in.)	0.34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Group A	A												
Group B		B	B	B	B	B	B	B	B	B	B	B	
Flexibility-- Weathered Panels--CAE													
Product	LPE	LE1	LE3*	LE4	LE5*	HPE							No analysis--no variation among panels
Mean (crack length in.)	1.67	0.0	0.0	0.0	0.0	0.0							
Group A	A												
Group B		B	B	B	B	B							
Flexibility-- Weathered Panels--PSI													
Product	LPE	LE1	LE3*	LE4	LE5*	HPE							No analysis--no variation among panels
Mean (crack length in.)	0.29	0.0	0.0	0.0	0.0	0.0							
Group A	A	A	A	A	A	A							
Impact Resistance-- Unexposed Panels--CAE	No analysis - only one result per product												No analysis--only one result per product
Impact Resistance-- Unexposed Panels--PSI	No analysis - only one result per product												No analysis--only one result per product

::

- Because of the lack of variability in the test results, the multiple comparisons analysis simply differentiated the paint HPI from the rest of the liquid products (Table 17).

Weathered Panels

Flexibility data for the weathered panels are presented in Figure 12. In this case three replicate panels were to be tested for each of the nine exterior products. As indicated in Table 11 there were a few panels at each laboratory that could not be tested. As with the unexposed panels, cementitious product RE1 could not be tested because it was too thick to fit in the test apparatus, accounting for three missing panels at each laboratory. Also, at CAE one RE2 panel and two RE3 panels lost adhesion prior to testing, and the same problem was experienced at PSI for one RE3 panel.

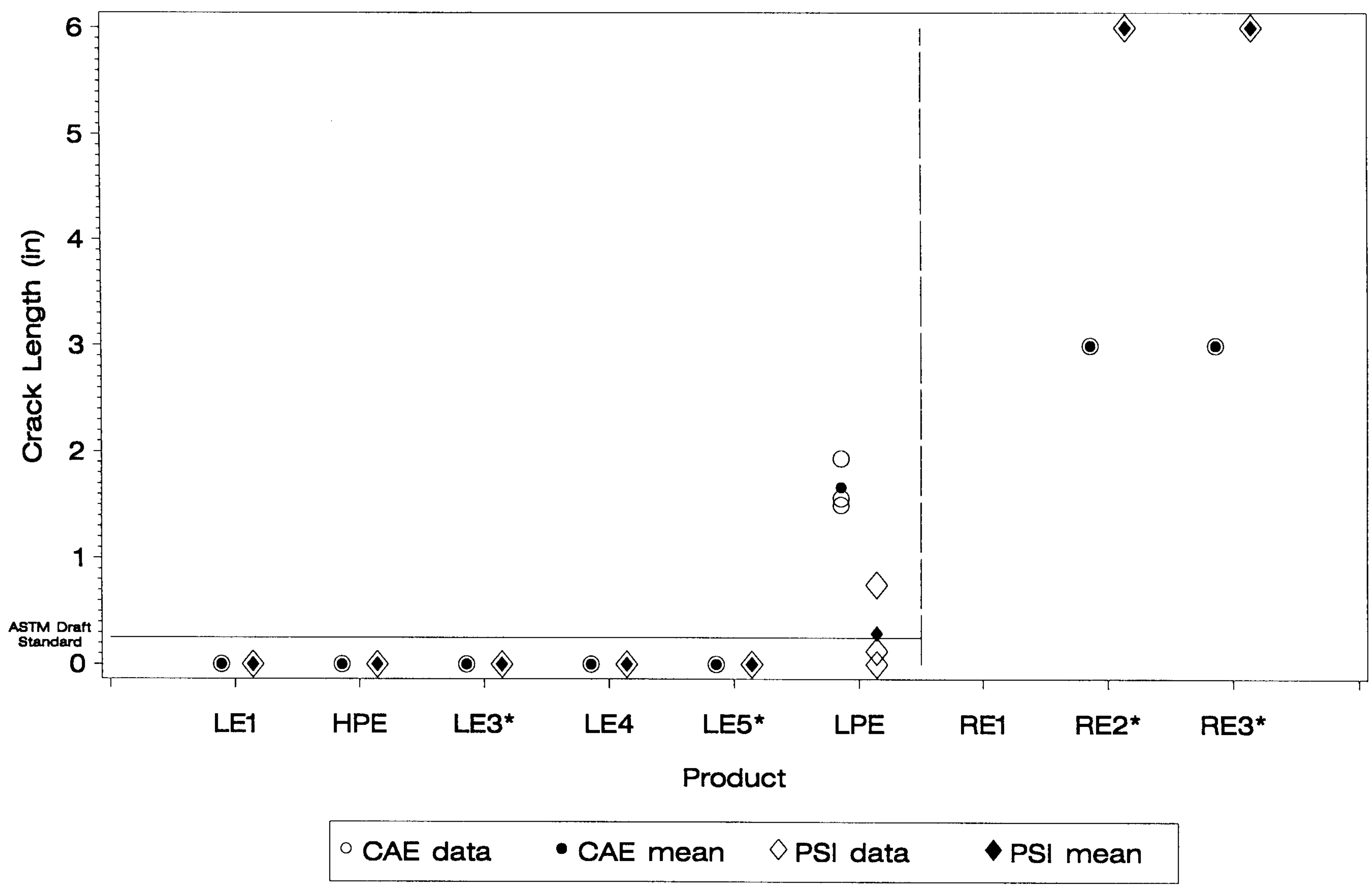
The weathered flexibility results were quite similar to those for the unexposed panels, except that in this case the low-quality exterior paint LPE experienced cracking while for the unexposed panels the high-quality interior paint cracked. Results from the statistical analysis of these results are summarized below:

- Of the 6 liquid products tested at CAE and PSI, all but one product, the low-quality exterior paint (LPE) tested at both CAE and PSI, achieved flexibility results below the draft ASTM E06.23.30 standard of a 0.25 inch crack length. There is currently no draft ASTM standard for reinforced products.

- The reinforced exterior products RE2 and RE3 cracked along their entire length, and the only other product to crack was the paint LPE.

- As a result of the cracking of paint LPE, there was a statistically significant difference between the mean crack length for encapsulants and paints, even though there was no cracking in the other paints. This difference was estimated as -0.83 inches at CAE and -0.15 inches at PSI (Table 13).

Figure 12
Flexibility Results for Weathered Panels



- No differences in flexibility were observed for replicate encapsulant products, and the multiple comparisons analysis simply distinguished the paint LPE from the rest of the liquid products at CAE (Table 17).

Summary of Flexibility Results

Very few unexposed or weathered products experienced cracking during the flexibility test. However, when cracking did occur it was for two paint products and one relatively inflexible reinforced encapsulant, the reinforced exterior acrylic and polyester composite encapsulant (RE2 and RE3). Therefore, while the study results do indicate that the flexibility protocol may be able to distinguish between some encapsulants (products RE2 and RE3) and paints (products HPI and LPE), most paints and encapsulants showed no differences with this test method.

4.8 IMPACT RESISTANCE

Impact resistance was measured for all 18 products on unexposed panels via direct impact with a 15.9 mm (0.625 inch) diameter indenter. Failure is defined as the first sign of surface cracking detectable by visual inspection aided by a 5x magnifier. The laboratories determined a failure point for each product by gradually increasing the distance from which the weight was dropped and examining the surface for cracking. A series of impacts was then performed above, at, and below this failure point to arrive at the end point in kilogram-meters (inch-lbs). The failure point was sometimes difficult to determine for multi-coat and reinforced products, especially those compressing on impact, because it was difficult to determine whether or not cracks were present.

According to ASTM, this test is subject to poor reproducibility from one laboratory to another. Therefore, results between laboratories are usually compared based on rankings of the actual results. If test data are to be determined by more than one laboratory, or products are to be tested at separate times and the data compared, each product could be tested against a known standard product on a pass/fail basis at a set level of performance, such as 80 inch-lbs.

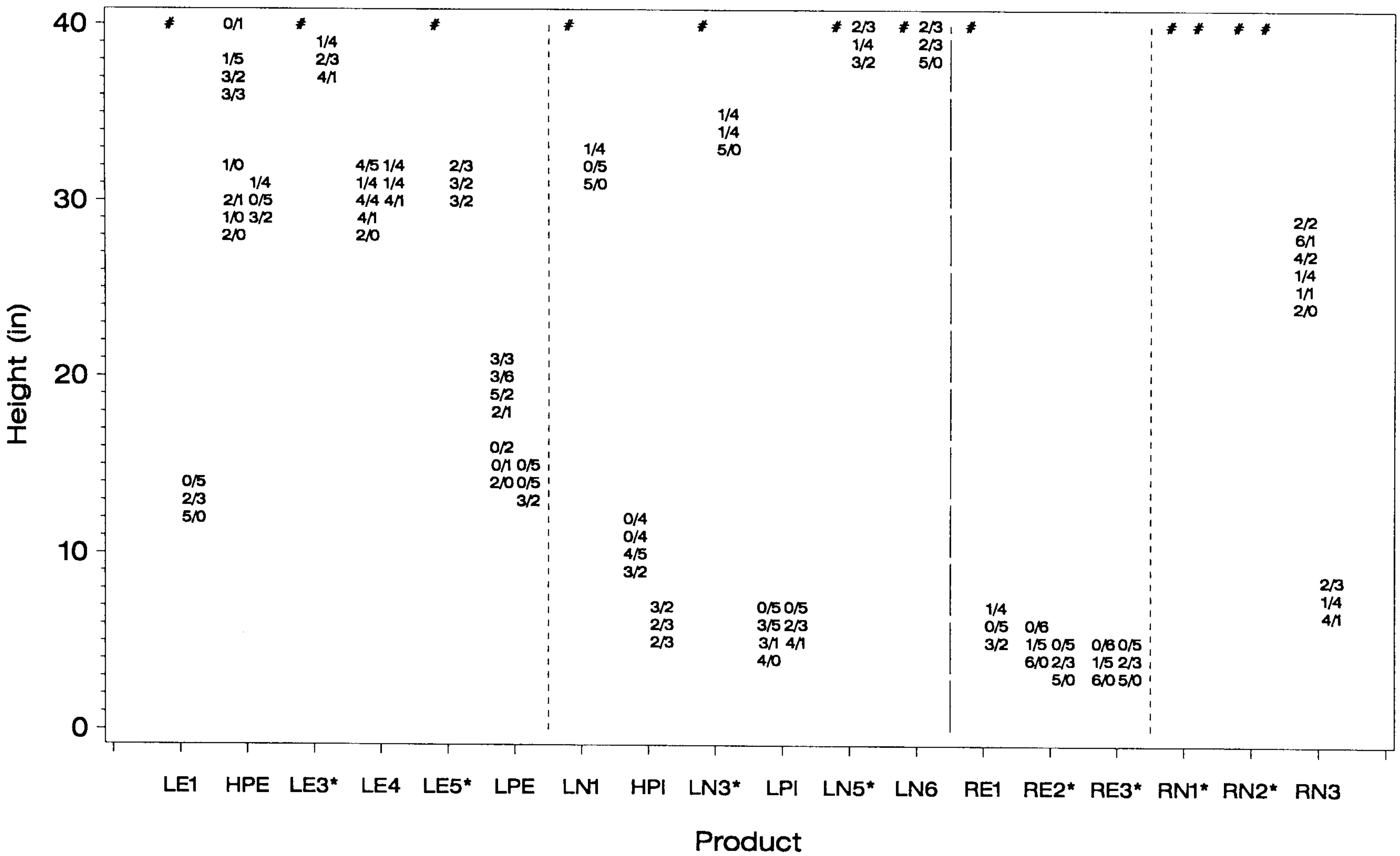
Variability of results from one laboratory to the other was evident in this study. In particular, the results for cementitious product RE1 were hard to interpret and the laboratories came to dramatically different conclusions. Compression damage to this product was evident starting at 4 inch-lbs but did not appear as definite cracks. In addition, impact at 160 inch-lbs did not produce more severe damage. There were no flakes, crumbling, or easily identifiable cracks at either the maximum or minimum impact for RE1. One laboratory determined that this product did not fail at the maximum impact, while the other determined the failure point at the first sign of deformation.

Results for Unexposed Panels

Results for impact testing on all 18 products are shown in Figures 13 and 14. Figure 13 displays the raw impact data by listing at each height the number of impacts which resulted in no visible surface cracking (pass) and the number of impacts which resulted in cracking (fail). As with previous figures, the CAE results for each product are shown as the left-hand column of data, while the PSI results are shown as the right-hand column. The final end point for each product was then determined as that height at which the impact results switch from mostly pass to mostly fail. These end points are presented in Figure 14. Note that for several products no surface cracking was observed, even up to the maximum force applied of 160 inch-lbs. Also note that the ASTM E06.23.30 draft performance standard of 80 inch-lbs has been added for reference to Figure 14. In addition, it can be seen in Figure 13 that the final end point for each product is not always obvious to determine. In some cases, such as the low-quality exterior paint (LPE) tested at CAE, fewer failures may

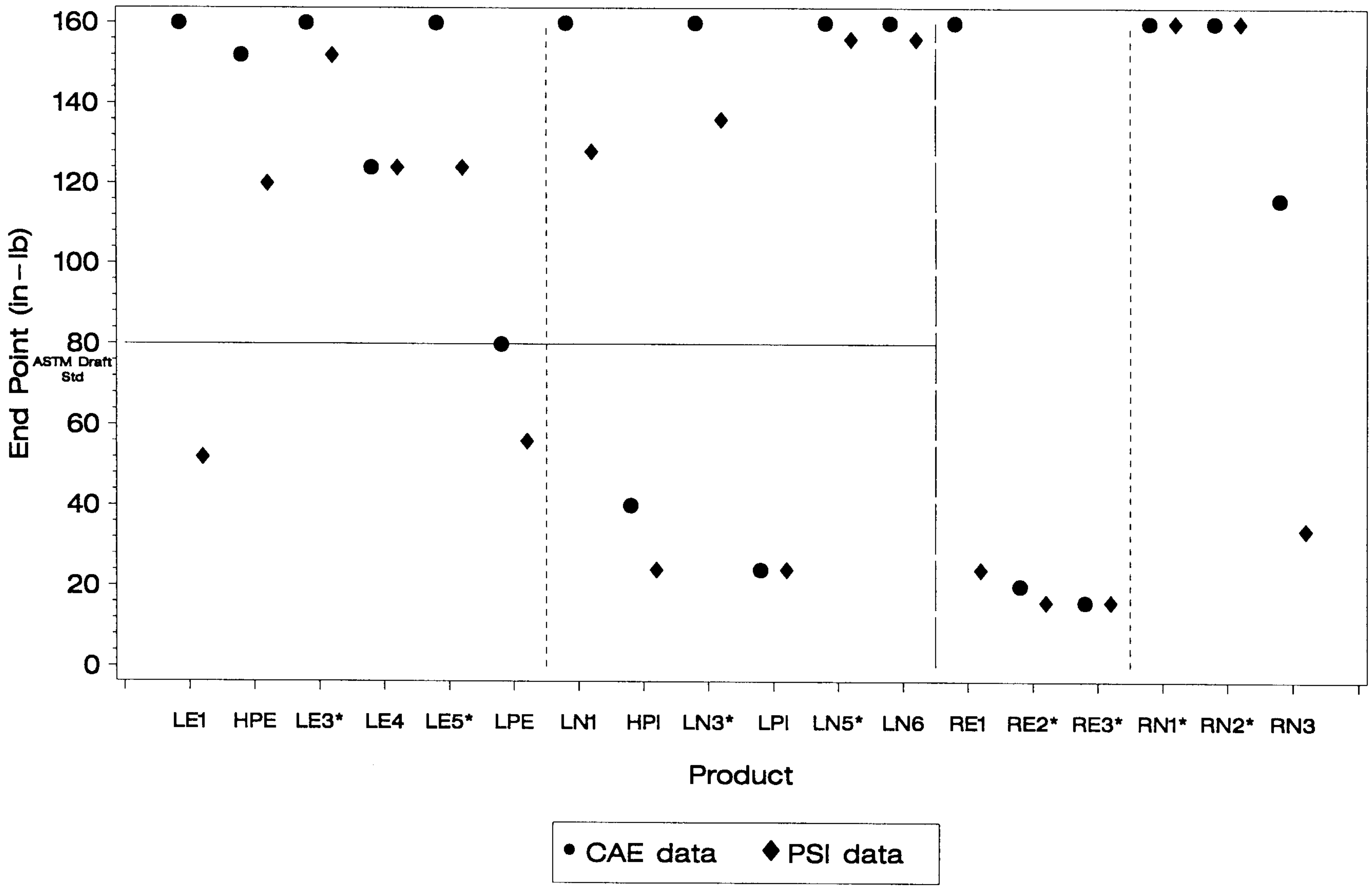
actually be found at some greater heights than at some lower heights. Also, even though the protocol called for five tests to

Figure 13
Impact Resistance Pass/Fail Frequencies for Unexposed Panels



Product did not crack.

Figure 14
Impact Resistance Results for Unexposed Panels



be performed at each height close to the final end point (i.e., at the end point, as well as one inch below and one inch above the end point), there were sometimes fewer, or more, than five tests run. In most cases these differences did not appear to seriously affect determination of the final end point, although as noted above, several of the final end points must be considered uncertain.

Because only one impact resistance result was obtained for each product, no estimate of measurement variability could be calculated, no tests of statistical significance could be performed, and no multiple comparisons among products could be made (Table 17). However, the statistical results which could be determined are presented in Tables 12 and 13, and summarized below:

- Of the 12 liquid products tested at CAE and PSI, all but 6 products achieved the draft ASTM E06.23.30 standard of 80 inch-lbs. Those products not achieving the draft ASTM standard were the liquid exterior hybrid copolymer latex encapsulant (LE1) tested at PSI, the low-quality exterior paint (LPE) tested at PSI, and the high-quality (HPI) and low-quality (LPI) interior paints tested at both CAE and PSI. No draft ASTM standard currently exists for reinforced products.

- Impact resistance measured by CAE was higher than, or equal to, that measured by PSI for every product tested. On average the difference was 24 inch-lbs for liquid coatings and 37 inch-lbs for reinforced products (Table 13). However, for three products (LE1, RE1, and RN3) the differences between results for CAE and PSI were much greater (Figure 14). As noted earlier, laboratory variability was at least partly due to difficulties identifying cracks for some products, such as RE1.

- Differences between replicate encapsulant products were reasonably small (Table 13), particularly for CAE (0 to 4 inch-lbs), but for PSI they were somewhat larger (0 to 28 inch-lbs).

- Impact resistance for the liquid encapsulants was from 68 to 80 inch-lbs higher than that for the paints (Table 13).

- Impact resistance for the liquid products averaged 115 inch-lbs which was higher than the average impact resistance for reinforced products at 99 inch-lbs (Table 12). However, it should be remembered that the impact resistance was quite different among the various products tested, so those average values should not be taken as indicators of general trends between the liquid and reinforced products.

Summary of Impact Resistance Results

The impact resistance test does appear to be able to distinguish among some products. The average impact resistance for liquid encapsulants was about 70-80 inch-lbs higher than that for paints. Also, three of the four paints tested had estimated impact resistance below the ASTM E06.23.30 draft standard of 80 inch-lbs, while only one liquid encapsulant (LE1) had an impact resistance less than the standard. The test also appeared to clearly identify products RE2 and RE3 as having low impact resistance in comparison with the other reinforced products, although for two of the other products (RE1 and RN3) differences between the two testing laboratories were quite large. In general, differences between the replicate encapsulant products and between the two laboratories were reasonably small, although impact resistance measured by CAE was consistently higher than, or equal to, that measured by PSI.

4.9 DRY ABRASION RESISTANCE

Dry abrasion resistance was determined for all 18 products on unexposed panels. Each product system was applied to S-16 commercial steel panels at the thickness recommended by the manufacturer. The sample surface was abraded by rotating the panel under 1000 gram weighted abrasive wheels (CS-17). Wheels were resurfaced after each 500 cycles of abrasion, and testing was continued to failure or 5000 cycles to yield maximum information about the range of product performances. Failure was defined as removal of the product to expose the metal substrate.

Results for two coatings are most comparable when those coatings are applied at the same thickness. However, this study was designed to provide information about the range of results attainable by a variety of products at their optimum performance. Therefore, each was applied at the thickness recommended for that product system. Some products were thin, some were two or more coats, and some included reinforcing materials. The variation in thickness alone was 4 mils to more than 300 mils. Since failure was defined as wear through to the test panel, thick product systems could lose more mass than thin products without failing.

All products were abraded with CS-17 wheels. However, at least one of the reinforced products (RE1) was so rough and abrasion resistant that CS-17 wheel wear was excessive. There are harder wheels available commercially for the Taber Abraser test apparatus but using wheels of different hardnesses in a comparative test makes comparison of dry abrasion resistance performance difficult.

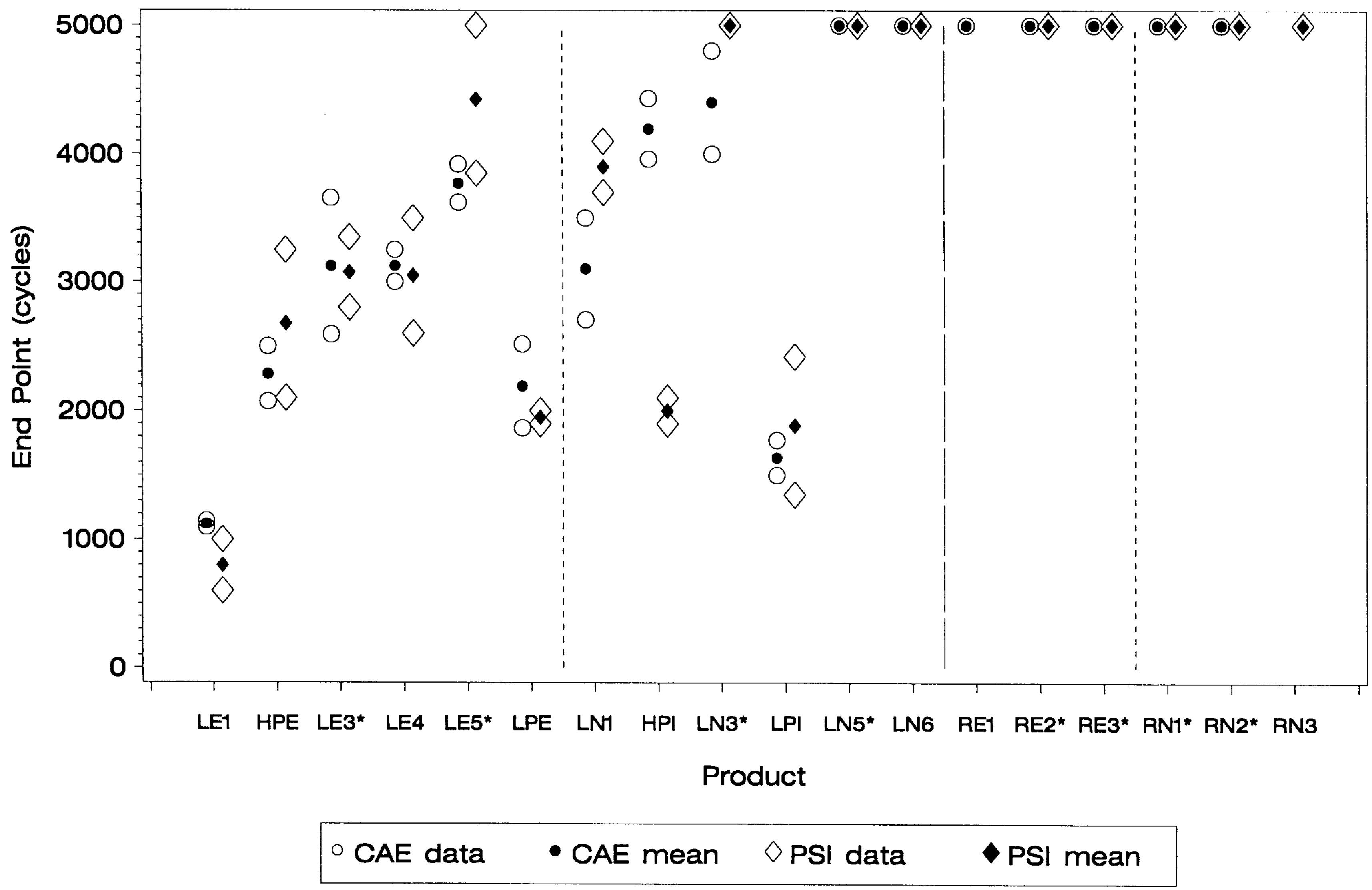
This test has poor interlaboratory reproducibility according to ASTM. Interlaboratory agreement may be improved significantly when rankings of coatings are used in place of numerical values. Numerical values can more reliably be compared when all testing is performed in one laboratory on coatings of the same thickness using the same test conditions.

<u>Cycles to Failure or End Point</u>

The dry abrasion resistance cycles to failure results are presented in Figure 15 for each of the 18 products tested. As shown in Table 11, two panels were to be tested for each product, and most anticipated results were successfully reported by both laboratories. However, both laboratories had two cases where complete results were not obtained. For product RN3, CAE prematurely stopped the testing of both replicate panels after 3500 cycles when the reinforcing mat appeared, even though the

coating had not yet been abraded completely through to the substrate. PSI did not finish testing one RE1 panel because excessive wear of the CS-17 wheels was occurring; and then because of this result, they did not attempt testing on the

Figure 15
Dry Abrasion End Point Results for Unexposed Panels



second RE1 panel. Similar to the scrub resistance data presented earlier, Figure 15 indicates that some encapsulant systems, particularly the reinforced systems, are durable enough and/or thick enough to survive dry abrasion for a full 5000 cycles. This fact results in some censored data which can affect the statistical results that follow.

Findings from the statistical analyses are shown in Tables 12, 13, and 18, and can be summarized as follows:

- **Since this study was initiated, the ASTM E06.23.30 Task Group has decided to set the standard for this test in terms of the loss in film thickness, rather than the cycles to end point or weight loss. Therefore, the testing results from this study can not be directly evaluated against the draft ASTM standard.**

- **Every panel for the reinforced coatings, with the exception of CAE's testing of product RN3 and PSI's testing of product RE1, lasted the full 5000 cycles; and even in these other cases, the testing was stopped although no failure had occurred.**

- **For liquid coatings the cycles to end point ranged from failure at 600 cycles to full testing at 5000 cycles (Table 12). It is also interesting to note the reasonably good agreement of the testing results for CAE and PSI with the possible exception of standard interior paint HPI (Figure 15).**

- **Measurement variability among replicate test panels was relatively low, ranging from 12% to 15% of the mean (Table 13); however, data censoring may have resulted in an underestimation of that variability.**

- **Variability between replicate encapsulant products was not significant for reinforced coatings or liquid coatings tested by CAE, but it was significant for liquid coatings tested by PSI due to the large differences observed between exterior products LE3 and LE5 (Table 13).**

- **The average end point for liquid encapsulants was found at both laboratories to be significantly greater than that for paints (Table 13). Based on CAE results the difference was estimated to be 838 cycles, while the PSI results indicated the difference at 1456 cycles.**

Table 18. Results of Multiple Pairwise Comparisons for Dry Abrasion Resistance Testing

Test Type	Liquid Products												Reinforced Products					
Dry Abrasion Resistance--Endpoint--CAE																		
Product	LN5*	LN6	LN3*	HPI	LE5*	LE4	LE3*	LN1	HPE	LPE	LPI	LE1	No analysis--no variation among panels					
Mean (cycles)	5000	5000	4401	4196	3772	3126	3124	3102	2286	2192	1637	1120						
Group A	A	A	A	A	A													
Group B			B	B	B	B	B	B										
Group C					C	C	C	C	C									
Group D						D	D	D	D	D	D							
Group E									E	E	E	E						
Dry Abrasion Resistance--Endpoint--PSI																		
Product	LN3*	LN6	LN5*	LE5*	LN1	LE3*	LE4	HPE	HPI	LPE	LPI	LE1	No analysis--no variation among panels					
Mean (cycles)	5000	5000	5000	4425	3900	3075	3050	2675	2000	1950	1885	800						
Group A	A	A	A	A	A													
Group B				B	B	B	B	B										
Group C						C	C	C	C	C	C							
Group D									D	D	D	D						
Dry Abrasion Resistance--Loss at 1000 Cycles--CAE																		
Product	LE1	LPE	LPI	HPE	LN3*	HPI	LN5*	LE3*	LE5*	LE4	LN6	LN1	RE1	RN3	RE2*	RN2*	RE3*	RN1*
Mean (g)	0.42	0.29	0.26	0.20	0.20	0.19	0.18	0.17	0.17	0.16	0.14	0.11	0.17	0.15	0.15	0.13	0.12	0.11
Group A	A												A	A	A	A	A	A
Group B		B	B															
Group C			C	C	C													
Group D				D	D	D	D	D	D	D	D							
Group E							E	E	E	E	E	E						
Dry Abrasion Resistance--Loss at 1000 Cycles--PSI																		
Product	LE1	LPI	HPI	LPE	HPE	LN6	LE4	LE3*	LN3*	LN1	LN5*	LE5*	RE3*	RE2*	RN3	RE1	RN1*	RN2*
Mean (g)	0.55	0.28	0.28	0.27	0.25	0.19	0.17	0.16	0.14	0.14	0.10	0.09	0.20	0.19	0.19	0.15	0.08	0.02
Group A	A												A	A	A	A		
Group B		B	B	B	B	B	B	B								B	B	
Group C					C	C	C	C	C	C							C	C
Group D						D	D	D	D	D	D	D						

::

Table 18. Continued

Test Type	Liquid Products												Reinforced Products					
Dry Abrasion Resistance--Loss at Endpoint--CAE																		
Product	LN3*	LN6	LN5*	HPI	LPE	LE5*	LE3*	HPE	LE4	LE1	LN1	LPI	RE2*	RE3*	RN1*	RE1	RN2*	RN3
Mean (g)	0.87	0.76	0.75	0.70	0.66	0.59	0.58	0.56	0.49	0.48	0.44	0.43	0.55	0.50	0.49	0.48	0.46	0.46
Group A	A	A	A	A	A								A	A	A	A	A	A
Group B		B	B	B	B	B	B	B										
Group C				C	C	C	C	C	C	C								
Group D					D	D	D	D	D	D	D	D						
Dry Abrasion Resistance--Loss at Endpoint--PSI																		
Product	LN3*	LN6	LPE	HPE	HPI	LN1	LPI	LE4	LE3*	LE1	LN5*	LE5*	RE3*	RN3	RE2*	RN1*	RN2*	
Mean (g)	0.85	0.82	0.71	0.62	0.56	0.54	0.51	0.50	0.47	0.45	0.42	0.35	0.82	0.78	0.65	0.38	0.06	
Group A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A			
Group B														B	B	B		
Group C																C	C	
Dry Abrasion Resistance--Wear Index--CAE																		
Product	LE1	LPE	LPI	HPE	LN3*	LE3*	HPI	LE4	LE5*	LN6	LN5*	LN1	RN3	RE2*	RE3*	RN1*	RE1	RN2*
Mean (g/1000 cycles)	0.43	0.30	0.26	0.25	0.20	0.19	0.17	0.16	0.16	0.15	0.15	0.15	0.13	0.11	0.10	0.10	0.10	0.09
Group A	A												A	A	A	A	A	A
Group B		B	B	B														
Group C			C	C	C	C												
Group D				D	D	D	D											
Group E					E	E	E	E	E	E	E	E						
Dry Abrasion Resistance--Wear Index--PSI																		
Product	LE1	LPE	HPI	LPI	HPE	LN3*	LE4	LN6	LE3*	LN1	LE5*	LN5*	RE3*	RN3	RE2*	RN1*	RN2*	
Mean (g/1000 cycles)	0.57	0.37	0.28	0.27	0.24	0.17	0.17	0.16	0.16	0.14	0.08	0.08	0.16	0.16	0.13	0.08	0.01	
Group A	A												A	A	A			
Group B		B	B	B	B	B	B							B	B	B		
Group C			C	C	C	C	C	C	C	C	C					C	C	
Group D				D	D	D	D	D	D	D	D	D						

::

- The multiple comparisons analysis could not be performed for the reinforced products, but for the liquid coatings 4 or 5 overlapping groups were distinguished where the groups with lowest end points contained the paints and encapsulant LE1, and the groups with highest end points generally contained the other interior encapsulants (Table 18).

Weight Loss at 1000 Cycles

Whereas the cycles to failure presented in the previous section provided a measure of both the durability and thickness of an encapsulant system, weight loss at 1000 cycles and wear index (i.e., weight loss per 1000 cycles over entire testing period) primarily measured the durability of the coatings. (Note: The term weight loss is used here in accordance with the ASTM method; however, the units reported, grams, more accurately reflect the mass loss.) Figure 16 shows the weight loss at 1000 cycles measured for all 18 of the products tested. Completeness for these data was quite good with only two values missing (Table 11). The missing value at PSI resulted when the second cementitious panel (RE1) was not tested because excessive wear of the CS-17 wheels had resulted from testing the first cementitious panel. And the "unable to test" result for PSI was due to the fact that one panel for product LE1 only lasted to 600 cycles before failure, so the loss at 1000 cycles could not be measured.

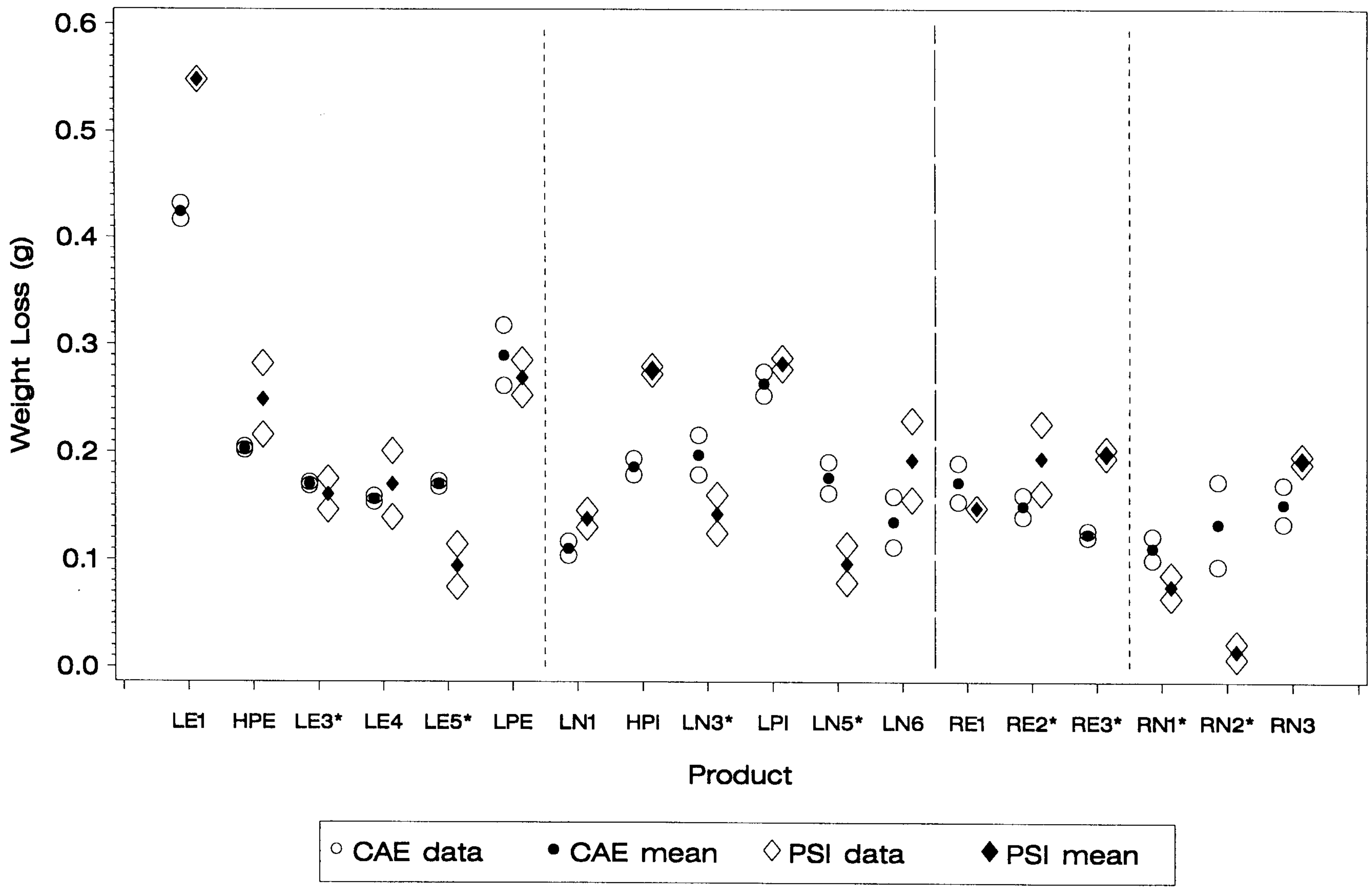
The statistical modeling results for these data are listed in Tables 12, 13, and 18, and can be summarized as follows:

- The weight loss during the first 1000 cycles for reinforced products averaged 0.14 grams, which was substantially less than that for liquid coatings which averaged 0.21 grams (Table 12). These results were also reasonably consistent between CAE and PSI (Figure 16 and Table 13).

- Measurement variability among replicate test panels was reasonably low, ranging from 10% to 21% of the mean for the two laboratories (Table 13).

- **Variability in weight loss between replicate encapsulant products was not judged to be statistically significant (Table 13).**

Figure 16
Dry Abrasion Weight Loss at 1000 Cycles Results for Unexposed Panels



- The mean weight loss at 1000 cycles for the liquid encapsulants was significantly less at both laboratories than the corresponding loss for paints. Based on data from CAE the difference was estimated to be -0.04 grams, and based on PSI data it was estimated at -0.05 grams (Table 13).

- The multiple comparisons analysis (Table 18) differentiated between 4 or 5 overlapping groups of liquid products, with the paints and encapsulant LE1 falling in groups with the greatest weight loss at 1000 cycles. For the reinforced products, the CAE results could not be differentiated into separate groupings of products, but the PSI results were separated into three groups with the acrylic products RN1 and RN2 experiencing the lowest losses.

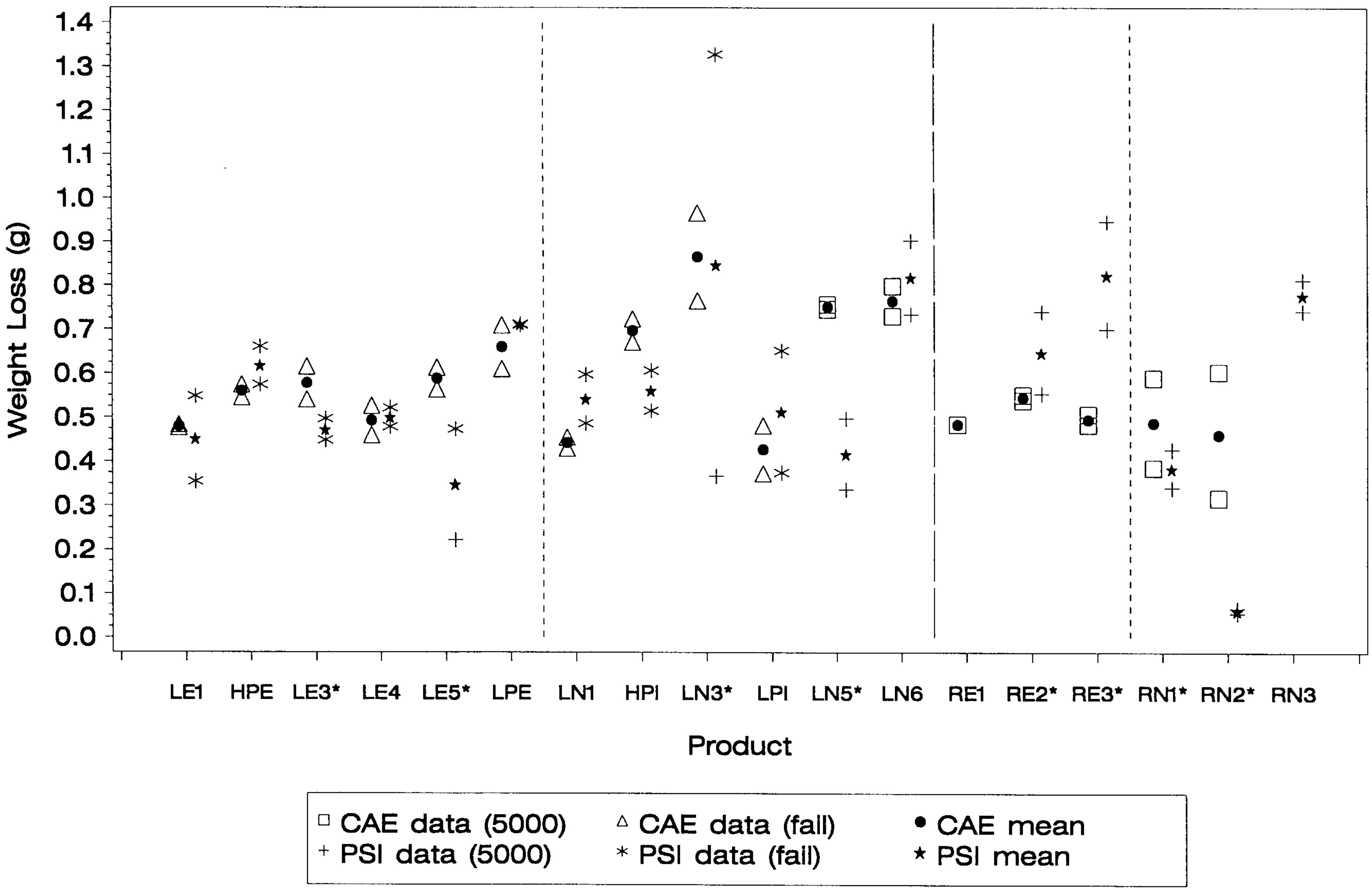
<u>Weight Loss at End Point</u>

For products where testing resulted in failure through to the substrate, the weight loss at end point provided an indirect measure of the original thickness of the coating. However, when trying to compare data across different products, this interpretation does not apply to coatings that reached the full 5000 cycles without failure. In those latter cases the weight loss is more comparable to the weight loss at 1000 cycles discussed in the previous section; that is, it measures mass lost from the coating during a fixed number of cycles. In this study all 20 reinforced product panels and 11 of 48 liquid product panels finished the protocol without failure through to the substrate, while the other 37 liquid product panels were abraded through to the substrate (previous Figure 15). As a result the combined data set for liquid products contains results corresponding to both situations described above, making the subsequent interpretation of results difficult.

Figure 17 illustrates the weight loss at end point measured for all 18 products tested. As shown in Table 11, all but four anticipated measurements were reported by the laboratories. For product RN3, CAE prematurely stopped testing both panels at 3500

cycles when abrasion wore through the topcoat to the reinforcing mat. For the cementitious product RE1, PSI stopped testing the

Figure 17
Dry Abrasion Weight Loss at End Point Results for Unexposed Panels



first panel before the end point was reached due to excessive wear of the CS-17 wheels, and then did not test the second panel because of the experience with the first. Also, note in Figure 17 that different plotting symbols were used within each laboratory to denote whether or not the measurement corresponds to weight loss at failure.

Results from the statistical analysis of these data are listed in Tables 12, 13, and 18 which are summarized in the following points:

- As shown in Table 12, weight loss at end point for reinforced products averaged 0.52 grams, which was less than that lost by liquid products (0.59 grams), even though the reinforced products were tested for a greater number of cycles (5000 cycles) than the liquid products (average 3238 cycles). These results were reasonably consistent at the two testing laboratories (Table 13).

- Measurement variability among replicate test panels differed somewhat between types of coatings (e.g., liquid vs. reinforced) and laboratories, ranging from 10% to 39% of the mean.

- Variability between replicate encapsulant products was not found to be significant except for reinforced products tested at PSI (Table 13). As shown in Table 18, this result appears to be mostly related to the relatively small weight loss seen for product RN2 (0.06 grams) as compared with product RN1 (0.38 grams).

- The mean weight lost at end point for liquid encapsulants was not found to be significantly different from that lost by the paints (Table 13). This result is explained by the fact that the encapsulants were tested for a significantly greater number of cycles than were the paints (average 838 more cycles at CAE, and average 1456 more cycles at PSI).

- No clear trends were found in the results from the multiple comparisons analysis (Table 18). No groups were distinguished for reinforced products tested at CAE or liquid products tested at PSI, and the groups differentiated for liquid products at CAE and reinforced products at PSI showed no clear separation by different types of products.

Wear Index

Wear index for a particular panel was measured as the weight lost per 1000 cycles of wear calculated across the entire duration of the test procedure to either failure or 5000 cycles. As such, it provides information similar to the weight loss at 1000 cycles which was discussed earlier, except that wear index considers loss across the entire test rather than just across the first 1000 cycles. Both types of measurements focus on the durability, rather than the thickness, of the product being tested.

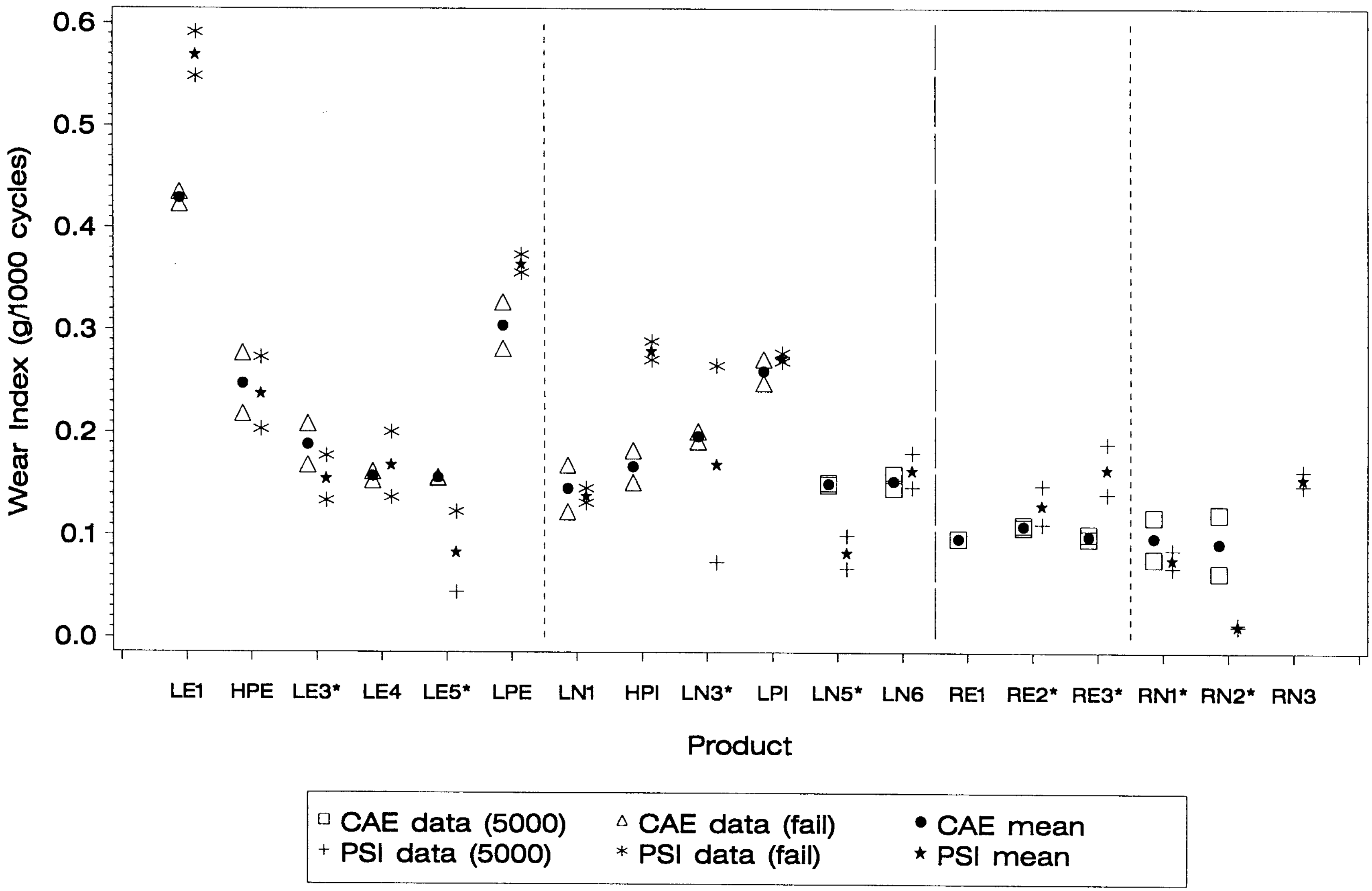
Figure 18 illustrates the wear index results for all 18 coatings products. Data completeness in this case was exactly the same as for weight loss at end point which was discussed earlier (Table 11). All but four planned measurements were reported. CAE stopped testing both RN3 panels at 3500 cycles when the abrasion wore through to the reinforcing mat. For the cementitious product RE1, PSI stopped testing the first panel before the end point due to excessive wear on the wheels, and then did not test the second panel to avoid additional excessive wear.

Results from the statistical analysis of wear index data are presented in Tables 12, 13, and 18, and are highlighted below:

- As shown in Table 12, the average wear index for reinforced products (0.10 grams/1000 cycles) was approximately half of that for liquid products (0.22 grams/1000 cycles). This difference was supported by the results from both testing laboratories (Table 13).
- Measurement variability was reasonably low for the wear index data, ranging from 10% to 23% of the mean at the two laboratories (Table 13).
- Variability between replicate encapsulant products was not found to be significant except for reinforced products tested at PSI (Table 13). This result appears directly related to the relatively low wear index for

product RN2 (0.01 grams/1000 cycles) in comparison with product RN1 (0.08 grams/1000 cycles).

Figure 18
Dry Abrasion Wear Index at End Point Results for Unexposed Panels



- **The mean wear index for liquid encapsulants was significantly less at both laboratories than the corresponding mean wear index for paints (Table 13). The difference was estimated to be -0.04 grams/1000 cycles based on data from CAE, and -0.07 grams/1000 cycles based on data from PSI.**

- **The multiple comparisons analysis (Table 18) distinguished 4 or 5 overlapping groups of liquid products, with the paints and encapsulant LE1 falling into groups with the highest wear indexes. For the reinforced products the CAE results could not be grouped, but the PSI results were differentiated into three groups with products RN1 and RN2 having the lowest wear indexes.**

Summary of Dry Abrasion Resistance Results

Results from this study indicate that the dry abrasion resistance test may be able to differentiate among different types of liquid products. In addition, even though all reinforced products completed the full 5000 cycles of abrasion without failure through to the substrate, this protocol calculates additional information, such as the wear index, that can be used to distinguish among reinforced products. Weight loss, both at 1000 cycles and in terms of the wear index, was greater for liquid coatings than for reinforced coatings. The loss per 1000 cycles for reinforced coatings (0.10 grams/1000 cycles) was approximately half of that for the liquid coatings. Also, the weight loss at 1000 cycles and the wear index were both greater for paints than for liquid encapsulants by about 0.04 to 0.07 grams/1000 cycles. Not surprisingly then, the average end point for liquid encapsulants was approximately 1000 cycles greater than the average end point for paints. Also, the replicate product variability was sometimes large for the liquid products, particularly for the cycles to end point, weight loss at end point, and wear index.

4.10 VISCOELASTIC PROPERTIES

Viscoelastic properties including tensile strength, elongation, and stiffness were determined for all 18 products. These properties may vary with film thickness, method of preparation, gauge length, type of grips and rate of load application. For this study, test parameters were set to film width of one inch, gauge[1] length of 1.5 inches, and crosshead[2] speed of 4 mm/minute. Free films for testing were produced on silicone release paper by drawdown except for RE1, the cementitious product, which was trowel applied. The free films were not all the same thickness, but varied from product to product. Free films of reinforced systems included the reinforcing mat. Some products, especially reinforced products RE1, RE2, RE3, and RN3, were difficult to cut into one-inch strips after the coating cured without introducing stress in the films. Nicks and jagged edges can reduce the tensile strength of the free films by acting as sites for tearing.

Ten free film strips were generally tested for each product; however, only the five film strips demonstrating the highest tensile strength were used for calculation of mean tensile strength, elongation, and stiffness. The five determinations displaying the lowest tensile strengths were eliminated from the calculation because film defects and handling damage can result in lower tensile strength results. Films can be easily damaged during handling or mounting, or by jaw slippage or tearing during testing.

Tensile strength is one of the most reported mechanical properties for materials characterization. Tensile strength in pounds per square inch (psi) is the load per unit area at which a test substance fails in a tension (pull) test. In this study,

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[1]According to ASTM D 2370 gauge length is the initial length of the test specimen between the jaws of the tensile tester.

[2]Crosshead speed is the speed at which the jaws travel during testing.

failure was the point at which the free film ruptured. For reinforced products, the reinforcing materials contribute a major component of the tensile strength. That is, the tensile strength of a reinforced product would likely increase or decrease if the reinforcement type were changed. For example, if a mat with increased tensile strength were incorporated into a product system, the tensile strength for the product system would be expected to reflect this increased tensile strength. Although four mat types were included in this study, no conclusions could be drawn from the data concerning relative tensile strengths of these four mats.

Elongation-at-break, reported as a percentage, describes the increase in specimen length from the point of initial load application to the point of film rupture in the tensile test. Stiffness is the ratio of the stress applied to the elongation observed. Stiffness (modulus of elasticity) was calculated as directed in the ASTM method for organic coatings.

<u>Tensile Strength</u>

The tensile strengths for all 18 products tested are shown in Figure 19. As shown in Table 11, results for five free films were used in the statistical analysis for each of the 18 products. However, one result for product LE3 at PSI was missing because only four free films could be retained intact. Figure 19 indicates that tensile strengths for the reinforced products were generally greater than those for the liquid products, but the variability in these results was also generally greater for reinforced products than for liquid products.

Statistical results for the tensile strength tests are presented in Tables 12, 13, and 19 which can be summarized by the points that follow:

- No draft ASTM E06.23.30 standard currently exists for any of the viscoelastic properties measured in this study (i.e., tensile strength, elongation, stiffness).

- **As shown in Table 12, the mean tensile strength for reinforced products (3366 psi) was much greater than that for liquid products (580 psi). This result was found for tests performed both at CAE and PSI, but it is also interesting to note that tensile strengths reported by CAE were almost always greater than or equivalent to those reported by PSI, with the exception of the cementitious product RE1 (Table 13 and Figure 19).**

Figure 19
Viscoelastic Tensile Strength Results for Unexposed Free Films

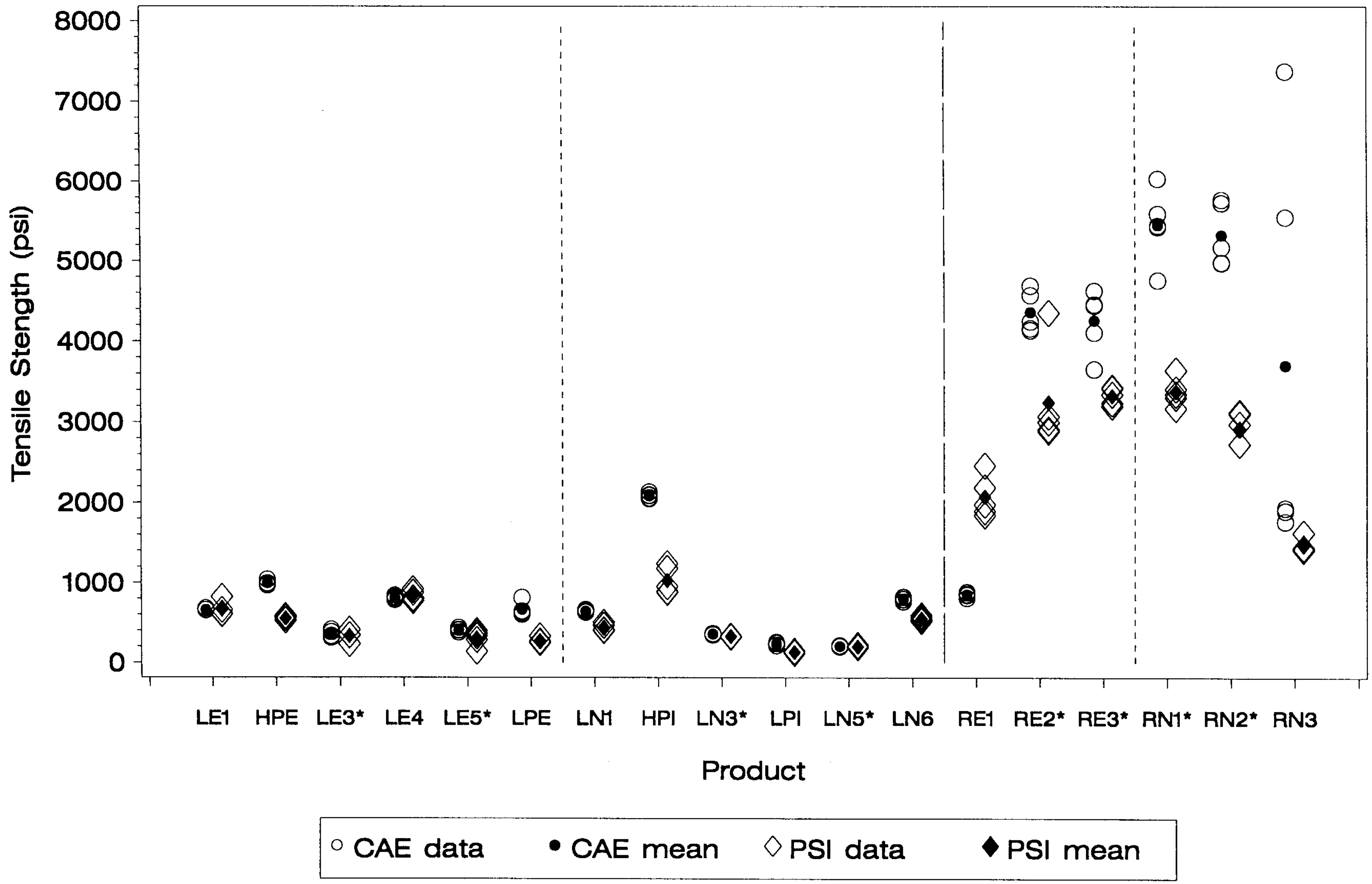


Table 19. Results of Multiple Pairwise Comparisons for Viscoelastic Properties

Test Type	Liquid Products												Reinforced Products					
Viscoelastic Properties-- Tensile Strength--CAE																		
Product	HPI	HPE	LE4	LN6	LPE	LE1	LN1	LE5*	LN3*	LE3*	LPI	LN5*	RN1*	RN2*	RE2*	RE3*	RN3	RE1
Mean (psi)	2085	994	810	805	664	661	642	406	358	353	236	208	5456	5331	4364	4261	3706	855
Group A	A												A	A	A	A	A	
Group B		B																B
Group C			C	C														
Group D					D	D	D											
Group E								E	E	E								
Group F											F	F						
Viscoelastic Properties-- Tensile Strength--PSI																		
Product	HPI	LE4	LE1	HPE	LN6	LN1	LE3*	LN3*	LE5*	LPE	LN5*	LPI	RN1*	RE3*	RE2*	RN2*	RE1	RN3
Mean (psi)	1030	834	662	553	552	437	332	328	303	273	202	133	3378	3327	3245	2932	2072	1468
Group A	A												A	A	A	A		
Group B		B															B	
Group C			C	C	C													C
Group D				D	D	D												
Group E						E	E	E	E									
Group F							F	F	F	F	F							
Group G										G	G	G						

::

Table 19. Continued

Test Type						Liquid Products										Reinforced Products		
Viscoelastic Properties--Elongation--CAE																		
Product	LE3*	LE5*	LN5*	LE4	LN6	LN1	LN3*	LPE	HPE	LE1	LPI	HPI	RN3	RE1	RN1*	RN2*	RE2*	RE3*
Mean (%)	479	419	258	253	219	153	71	63	17	10	8	1	19	8	8	6	6	5
Group A	A	A											A	A	A			
Group B			B	B	B									B	B	B	B	B
Group C					C	C												
Group D						D	D	D										
Group E							E	E	E	E	E	E						
Viscoelastic Properties--Elongation--PSI																		
Product	LE5*	LE3*	LN1	LN5*	LE4	LN6	LPE	LN3*	HPE	LPI	LE1	HPI	RN3	RN1*	RE1	RN2*	RE2*	RE3*
Mean (%)	576	332	328	274	265	216	72	48	38	17	15	1	27	17	11	8	6	4
Group A	A	A	A	A	A								A					
Group B		B	B	B	B	B	B	B	B	B	B	B		B	B			
Group C															C	C	C	
Group D																D	D	D
Viscoelastic Properties--Stiffness--CAE																		
Product	HPE	HPI	LE1	LPE	LN1	LPI	LN3*	LE4	LN5*	LE5*	LE3*	LN6	RN1*	RN2*	RN3	RE2*	RE3*	RE1
Mean (psi)	617	615	535	397	391	214	213	149	110	73	71	28	5024	4839	3036	2785	2374	632
Group A	A	A	A										A	A	A	A	A	
Group B				B	B										B	B	B	B
Group C						C	C	C	C									
Group D								D	D	D	D							
Group E									E	E	E	E						
Viscoelastic Properties--Stiffness--PSI																		
Product	HPI	LE1	LE4	HPE	LPE	LN6	LN1	LN3*	LPI	LN5*	LE3*		RE3*	RN2*	RE2*	RN1*	RN3	RE1
Mean (psi)	820	307	274	176	115	114	111	108	106	40	18		1579	1286	1254	1155	659	591
Group A	A												A	A	A	A		
Group B		B	B														B	B
Group C			C	C														
Group D				D	D	D	D	D	D									
Group E					E	E	E	E	E	E	E							

::

- Measurement variability in tensile strength among replicate free films was reasonably low at both laboratories, ranging from 5% to 28% of the mean (Table 13).

- Variability between replicate encapsulant products was not significant for reinforced products, but it was significant for liquid coatings with differences between the tensile strengths for replicate products ranging from 30 psi to 150 psi at the two laboratories (Table 13). The lack of significance for the reinforced products was probably due to the higher measurement variability found in comparison with the liquid products.

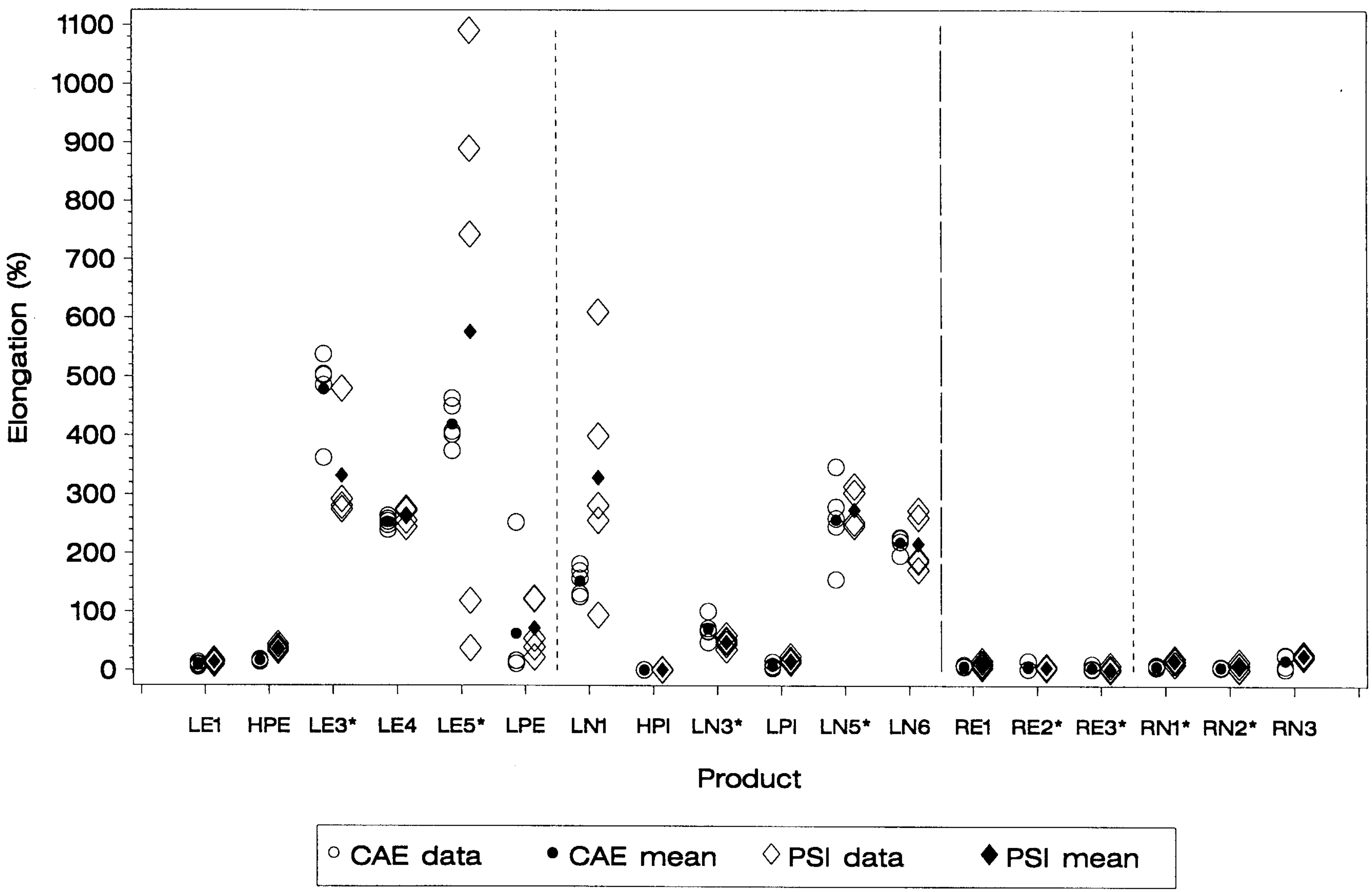
- The average tensile strength for liquid encapsulants based on PSI data was not found to be significantly different from that of paints; but CAE test results indicated that the average tensile strength for liquid encapsulants was significantly lower (-398 psi) than that for paints. CAE results showed that the two liquid products with the greatest tensile strengths were the high-quality interior (HPI) and exterior (HPE) paints (Table 19). The lack of significance in the PSI results is most likely due to the higher measurement variability found for that laboratory.

- The multiple comparisons analysis (Table 19) separated the coatings products into several groups based on tensile strength, but the groupings did not clearly distinguish between paints and encapsulants. For example, for the liquid products, the high-quality paints (HPI and HPE) and exterior acrylic encapsulant (LE4) were found to have relatively high tensile strengths.

Elongation

The elongation test results for all 18 products are presented in Figure 20. Just as for the tensile strength data discussed above, all but one of the planned elongation results were reported (Table 11). PSI could not measure one result for product LE3 because only four of five free films could be maintained intact. Figure 20 shows that elongation for the reinforced products was generally low in comparison with the liquid products, and that there was wide variability in elongation among the liquid products.

Figure 20
Viscoelastic Elongation Results for Unexposed Free Films



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Tables 12, 13, and 19 list results from the statistical analysis of the elongation data which can be summarized as follows:

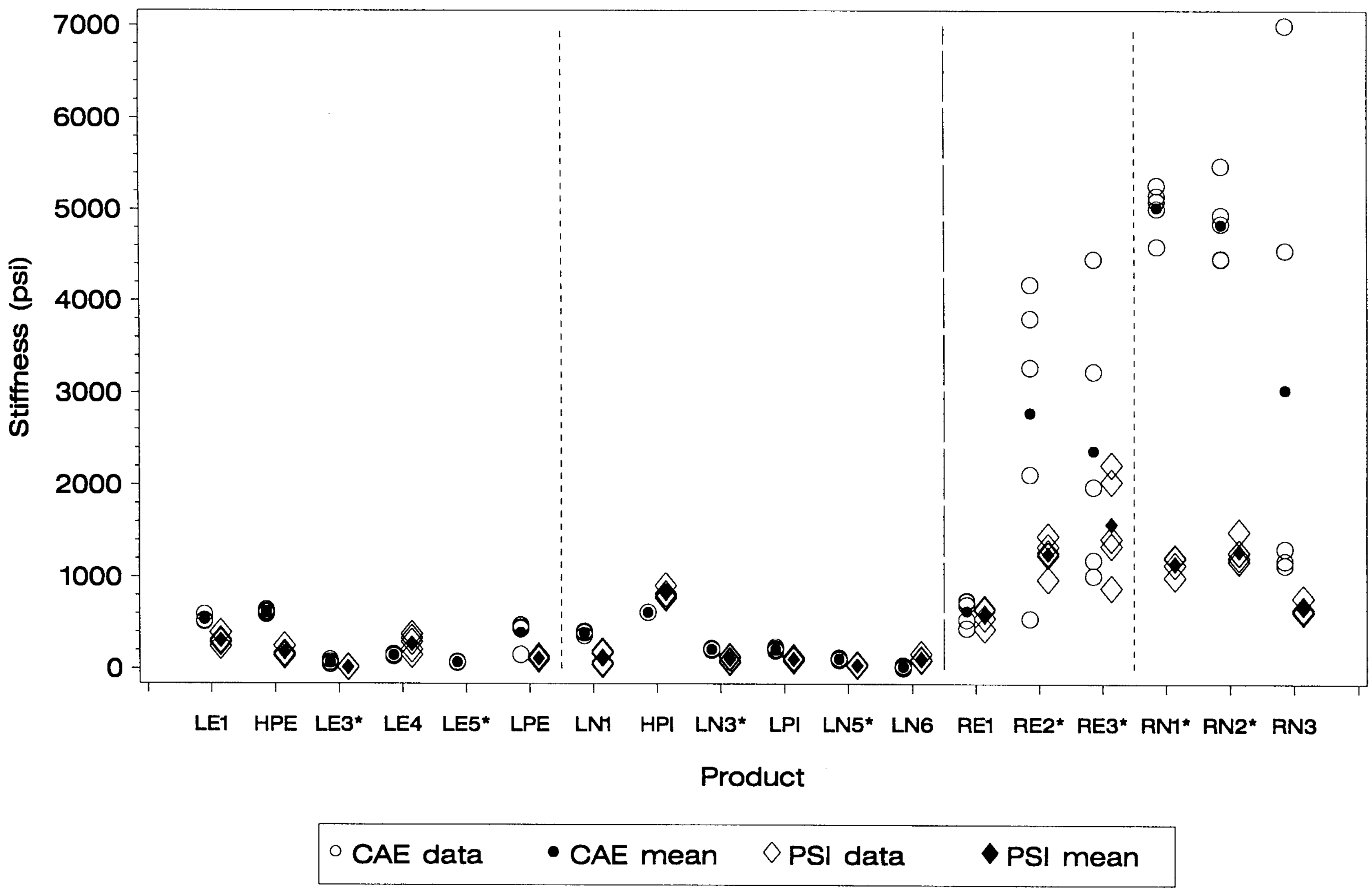
- Table 12 shows that the mean elongation for liquid products (171%) was much greater than the mean elongation for reinforced encapsulants (10%). Also, the results were fairly consistent for testing at CAE and PSI (Table 13), except that elongations measured by PSI for liquid products LE5 and LN1 were much more variable among replicate panels than corresponding elongations measured by CAE (Figure 20).
- Measurement variability among replicate free films was relatively high for the elongation tests, ranging from 27% to 85% of the mean (Table 13). This statement is particularly true of the PSI elongation measurements for liquid products LE5 and LN1.
- Variability between the elongation results for replicate encapsulant products was generally found to be statistically significant (Table 13), ranging between 59% and 244% for the liquid products, and between 1% and 9% for the reinforced products.
- The mean elongation for liquid encapsulants was significantly greater than that for paints; Table 13 indicates that the difference in elongation varied between 186% and 207% for tests performed at CAE and PSI.
- Results from the multiple comparisons analysis (Table 19) indicated that this test may be able to distinguish various product groupings. For example, at both CAE and PSI three paints (HPI, LPI, and HPE) and one hybrid latex encapsulant (LE1) exhibited the lowest elongations, while the liquid exterior acrylic latex encapsulant (LE3 and LE5) had the highest elongations.

Stiffness

Figure 21 presents the stiffness results for all 18 products tested. As shown in Table 11, there were 11 test results that were missing from the stiffness data set. CAE had four free films (all LN2) that broke before 1% elongation was achieved, and one film that was incorrectly measured due to an operator error.

The tensile tester generated continuous data from zero to break but stiffness is calculated by definition at the point of 1%

Figure 21
Viscoelastic Stiffness Results for Unexposed Free Films



elongation. PSI had five free films (all LE5) for which stiffness measurements could not be made, and one case where only four of five free films could be produced intact. Similar to the tensile strength measurements discussed previously, Figure 21 shows that the stiffness of the reinforced products was generally greater than that of the liquid coatings, and the variability of the stiffness data for the reinforced products was also greater than the variability of the liquid coating results.

Statistical modeling results for the stiffness data are listed in Tables 12, 13, and 19, and are summarized as follows:

- Table 12 shows that the mean stiffness for reinforced products (2101 psi) was nearly ten times greater than the mean stiffness for liquid products (233 psi). This same result was generally found for test results run at both CAE and PSI (Table 13). However, while reasonably good agreement between test results at CAE and PSI was observed for the liquid products (Figure 21), the agreement was not nearly as close for the reinforced products, where both the mean stiffness and variability among test results were much greater for the CAE data (except for the cementitious product RE1, where there was good interlaboratory agreement).

- Measurement variability in stiffness among replicate free films ranged from 17% to 45% of the mean, although the variability for reinforced products tested at CAE was much higher than for the PSI data and the CAE data for liquid products (Table 13).

- Variability between the stiffness measurements for replicate encapsulant products was not significant for reinforced products, but it was significant for liquid products (Table 13). Differences between the mean stiffness for replicate liquid encapsulants ranged from 2 psi to 103 psi. The lack of significance for reinforced products was probably due to higher measurement variability in comparison with the liquid products.

- The average stiffness for liquid encapsulants was significantly lower than that for paints; Table 13 indicates that the difference was -230 psi at CAE and -154 psi at PSI.

- Results from the multiple comparisons analysis indicate several possible groupings but no clear distinction among different types of products. However, for the liquid products, the high-quality interior paint (HPI) and hybrid latex exterior encapsulant (LE1) were generally found to have the greatest stiffness at both CAE and PSI.

Summary of Results for Viscoelastic Properties

The results of this study indicate clear differences between the viscoelastic properties of the liquid and reinforced coatings tested. In addition, the results sometimes indicated possible groupings among different types of products. Tensile strength and stiffness were generally much greater for reinforced products than for liquid products, due in part to the presence of the reinforcing mats. Conversely, elongation was generally much lower for reinforced products than for liquid products. Similarly, tensile strength and stiffness were higher, while elongation was lower, for the paints when compared with liquid encapsulants. These results were primarily due to the tensile strength and stiffness of the high-quality paints tested, rather than the low-quality paints. In addition, higher measurement variability was observed for the elongation data as compared with the tensile strength and stiffness measurements. For the tensile strength and stiffness data, greater variability was seen for the reinforced coatings than for the liquid products. Also, the variability between replicate encapsulant products was found to be significant for tensile strength and stiffness measured on the liquid products, as well as elongation measured on both the liquid and reinforced products. The lack of significance between replicate reinforced products for the tensile strength and stiffness tests was probably due to the higher variability found in these data.

4.11 BLISTERING

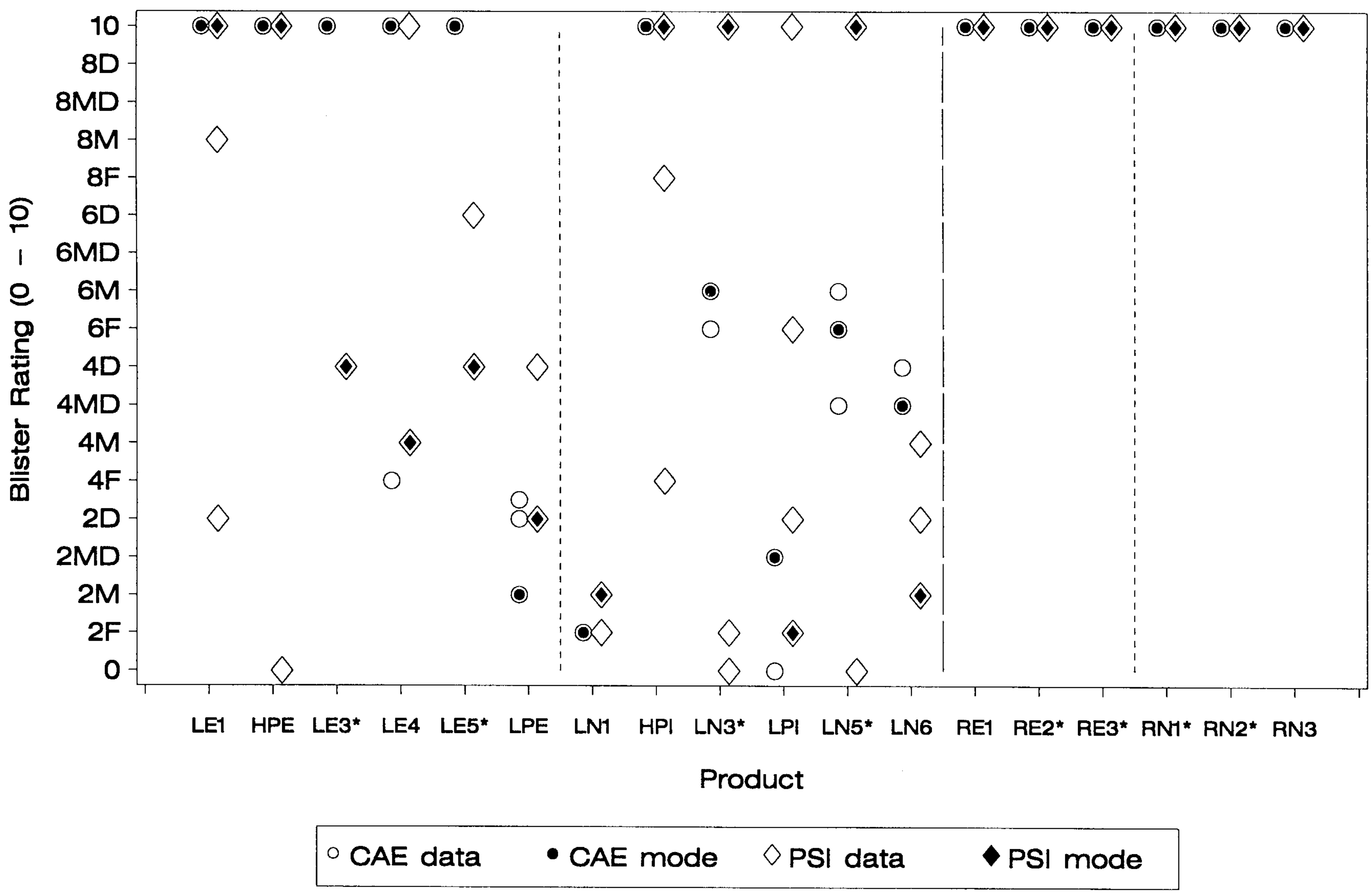
Blistering was evaluated for all 18 products following 24-hour water immersion, and for the nine exterior products following weathering. In this test, sample panels were compared with ASTM photographic reference standards to rate the size and frequency of blisters. The numerical scale for blister size runs from 10 to 0. A rating of 10 represents no blistering and a rating of 8 represents the smallest size blister that can be seen without magnification. The frequency of blistering at each numerical size was determined from the photographic reference and designated by adding D (dense), MD (medium dense), M (medium), or F (few) to the size rating (e.g., 8D). Blistering can be used as a rough visual gauge of adhesion loss through film defects or degradation.

Immersed Panels

The blistering test was run after a ten-minute dry for all panels that were subjected to the water immersion protocol. As shown in Table 11, this test was planned for 66 panels at each laboratory, and all but one of these results were reported. In the lone exception, CAE was unable to run the test because one RE3 panel lost adhesion before the water immersion protocol was initiated. Results from the blistering test, which are depicted in Figure 22, indicate that the reinforced products experienced no problems with blistering after water immersion, while the liquid products had a number of panels that blistered. One point to notice in Figure 22 is that the data for each product and laboratory are summarized by the sample mode (i.e., the most frequently occurring blister rating) rather than by the sample mean as in previous figures. This change was made in order to include the letter designations for the frequency of blisters.

Statistical analyses were performed using only the numerical part of the blister rating which measures the size of the blisters. It should be noted that this approach ignores the blister density and implicitly assumes that coatings forming many small blisters perform better than coatings forming a few larger blisters. Although these data are only semi-quantitative in nature, some useful results were obtained from the statistical analyses which are presented in Tables 12, 13, and 20, and summarized below:

Figure 22
Blistering Results for Immersed Panels



- **No draft ASTM E06.23.30 standard currently exists for the blistering test.**

- **All panels for the reinforced products received a blister rating of 10 indicating that no blisters were present. Because there was no variability in results observed for the reinforced products, this test was not able to distinguish among the various coatings, and no further statistical analysis could be performed.**

- **The mean blister rating for liquid products was 6 (Table 12), and roughly equivalent results were recorded by both CAE and PSI (Table 13).**

- **Variability between replicate encapsulant products was not found to be significant at either laboratory (Table 13).**

- **The average blister rating for liquid encapsulants tested at PSI was not found to be significantly different from that for paints (Table 13). In addition, the CAE data indicated a difference of 1, which was statistically significant but probably not practically significant.**

- **The multiple comparisons analysis of CAE data found the two low-quality paints and the interior encapsulant LN1 forming a group with the lowest ratings (i.e., the largest blisters).**

Weathered Panels

Figure 23 presents the blister ratings for all nine exterior products that were subjected to the weathering protocol. Data completeness in this case was excellent with all planned measurements being reported by both laboratories (Table 11). As can be seen in Figure 23, very few blisters were observed after weathering.

Results from the statistical analysis of these blistering data, which are listed in Tables 12, 13, and 20, can be summarized as follows:

- **All panels for the reinforced products received a blister rating of 10 indicating that no blisters were present. In addition, for the liquid products blisters were observed only for the low-quality exterior paint (LPE) and acrylic exterior encapsulant (LE4).**

Figure 23
Blistering Results for Weathered Panels

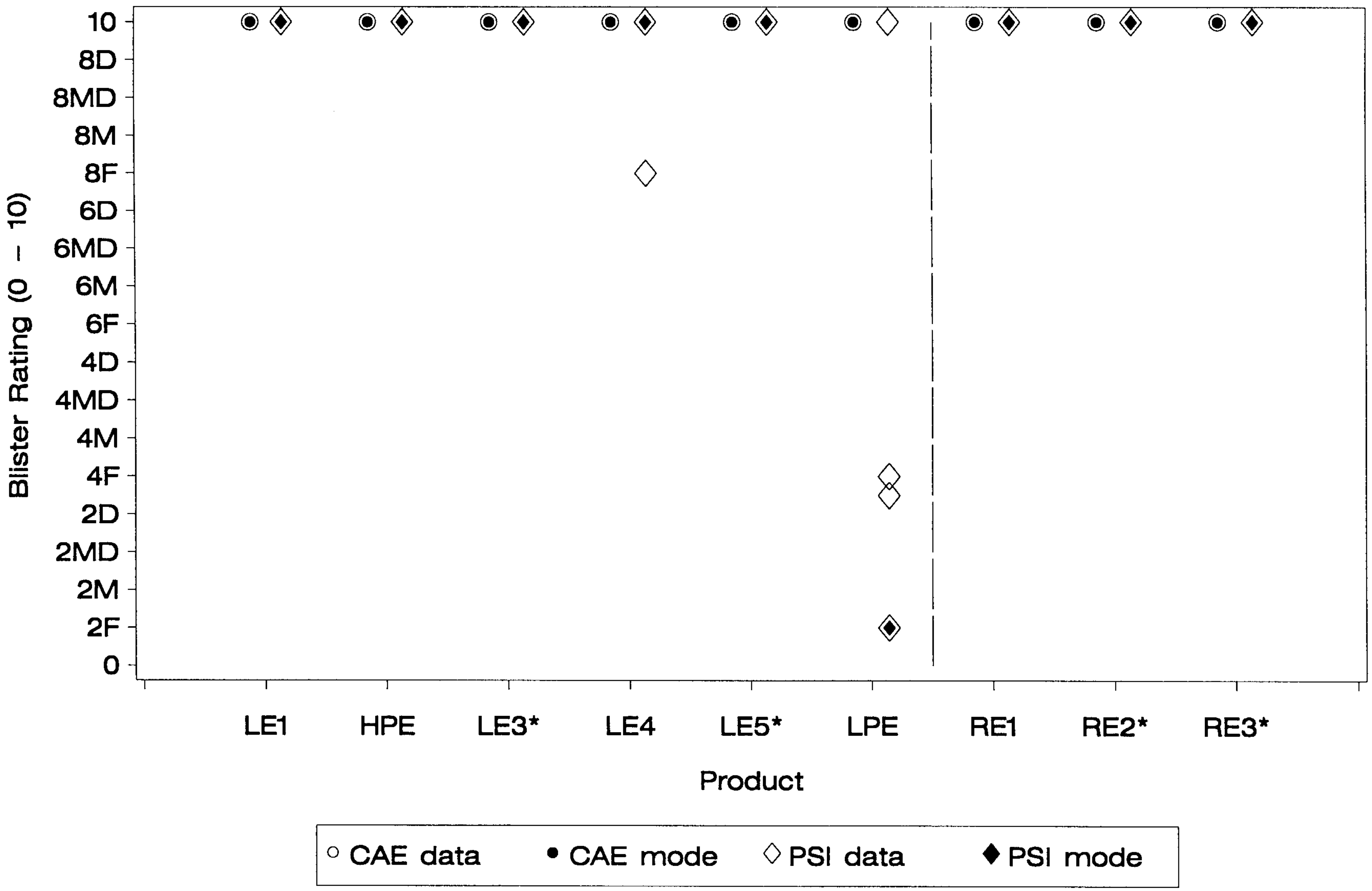


Table 20. Results of Multiple Pairwise Comparisons for Blistering and Chalking Tests

Test Type	Liquid Products												Reinforced Products		
Blistering--Immersed Panels--CAE															
Product	LE1	HPE	LE3*	HPI	LE5*	LE4	LN3*	LN5*	LN6	LPE	LN1	LPI	No analysis--no variation among panels		
Mean (0-10 rating)	10	10	10	10	10	9	6	6	4	3	2	2			
Group A	A	A	A	A	A	A									
Group B							B	B	B						
Group C									C	C	C				
Group D										D	D	D			
Blistering--Immersed Panels--PSI															
Product	HPI	LE1	LN5*	HPE	LE4	LN3*	LE5*	LPI	LE3*	LPE	LN6	LN1	No analysis--no variation among panels		
Mean (0-10 rating)	8	8	8	8	7	6	5	5	4	3	3	2			
Group A	A	A	A	A	A	A	A	A	A	A	A	A			
Blistering--Weathered Panels--CAE	No analysis--no variation among panels												No analysis--no variation among panels		
Blistering--Weathered Panels--PSI															
Product	LE1	HPE	LE3*	LE5*	LE4	LPE							No analysis--no variation among panels		
Mean (0-10 rating)	10	10	10	10	10	4									
Group A	A	A	A	A	A										
Group B						B									
Chalking--Weathered Panels--CAE															
Product	LE4	LE5*	LE3*	LPE	LE1	HPE							RE1	RE3*	RE2*
Mean (0-10 rating)	10	9	9	8	7	7							10	7	7
Group A	A	A	A										A		
Group B				B										B	B
Group C					C	C									
Chalking--Weathered Panels--PSI															
Product	LE5*	LE3*	LE4	HPE	LE1	LPE							RE1	RE2*	RE3*
Mean (0-10 rating)	8	8	8	8	7	7							8	7	7
Group A	A	A	A										A		
Group B				B	B	B								B	B

::

- No variability between replicate encapsulant products was observed at either testing laboratory (Table 13).
- For tests conducted at PSI, the average blister rating for liquid encapsulants was found to be 3 higher (i.e., smaller blisters were observed) than that for paints (Table 13). This difference was statistically significant, but probably not practically significant.
- The only differentiation among blister ratings for the liquid products that was determined by the multiple comparisons analysis was that the low-quality exterior paint had significantly lower ratings (i.e., larger blisters).

Summary of Results for Blister Ratings

The results of this study indicate that the blistering test may be able to distinguish between some different types of products. However, in this study this separation could only be made between encapsulants and low-quality paints; encapsulants and high-quality paints could not be distinguished. Furthermore, no blisters were observed for reinforced encapsulants, so no differentiation among these products could be made. In addition, far fewer blisters were seen after weathering than after water immersion, so the blistering test appears more likely to be able to differentiate among products when run in conjunction with the water immersion protocol.

4.12 CHALKING

Chalking was evaluated for the nine exterior products after being subjected to the weathering protocol. A black wool felt fabric was wrapped around the index finger and rubbed against the surface of the weathered panel through 180 degrees. The fabric surface was then compared visually with ASTM photographic reference standards. The rating scale for Method A was 0 to 10 with a rating of 10 indicating no visual evidence of chalking. Data were collected from more than one area on each panel and reported as a mean.

Chalking is the formation on a pigmented coating of a powder evolved from the film itself at, or just beneath, the surface. Therefore, the presence of chalk can indicate degradation of an exterior coating film.

<u>Weathered Panels</u>

Figure 24 shows the chalking ratings for all nine exterior products that were subjected to the weathering protocol. Also shown in the figure is the ASTM E06.23.30 draft performance standard for liquid coatings of 8. Data completeness for this test was excellent with all but one planned measurement being reported (Table 11). The single exception was one panel for acrylic exterior encapsulant LE4 which was so badly warped during weathering that further testing could not be completed. As can be seen in Figure 24, most panels exhibited some degree of chalking after weathering.

Tables 12, 13, and 20 present results from the statistical analysis of the chalking data. A summary of these results is provided in the following points:

- **Of the 6 liquid products tested at CAE and PSI, only 3 products at CAE met the draft ASTM E06.23.30 standard of 8 for all panels evaluated; those products were the acrylic latex encapsulants (LE3 and LE5) and the acrylic encapsulant (LE4). However, for one other product tested at CAE (LPE) and 3 other products tested at PSI (LE3, LE4, LE5), the average chalking result met the draft ASTM tandard. There is currently no draft ASTM standard for reinforced products.**

- **The average chalking rating was similar for reinforced (8) and liquid (8) products (Table 12), and for tests conducted by CAE and PSI (Table 13).**

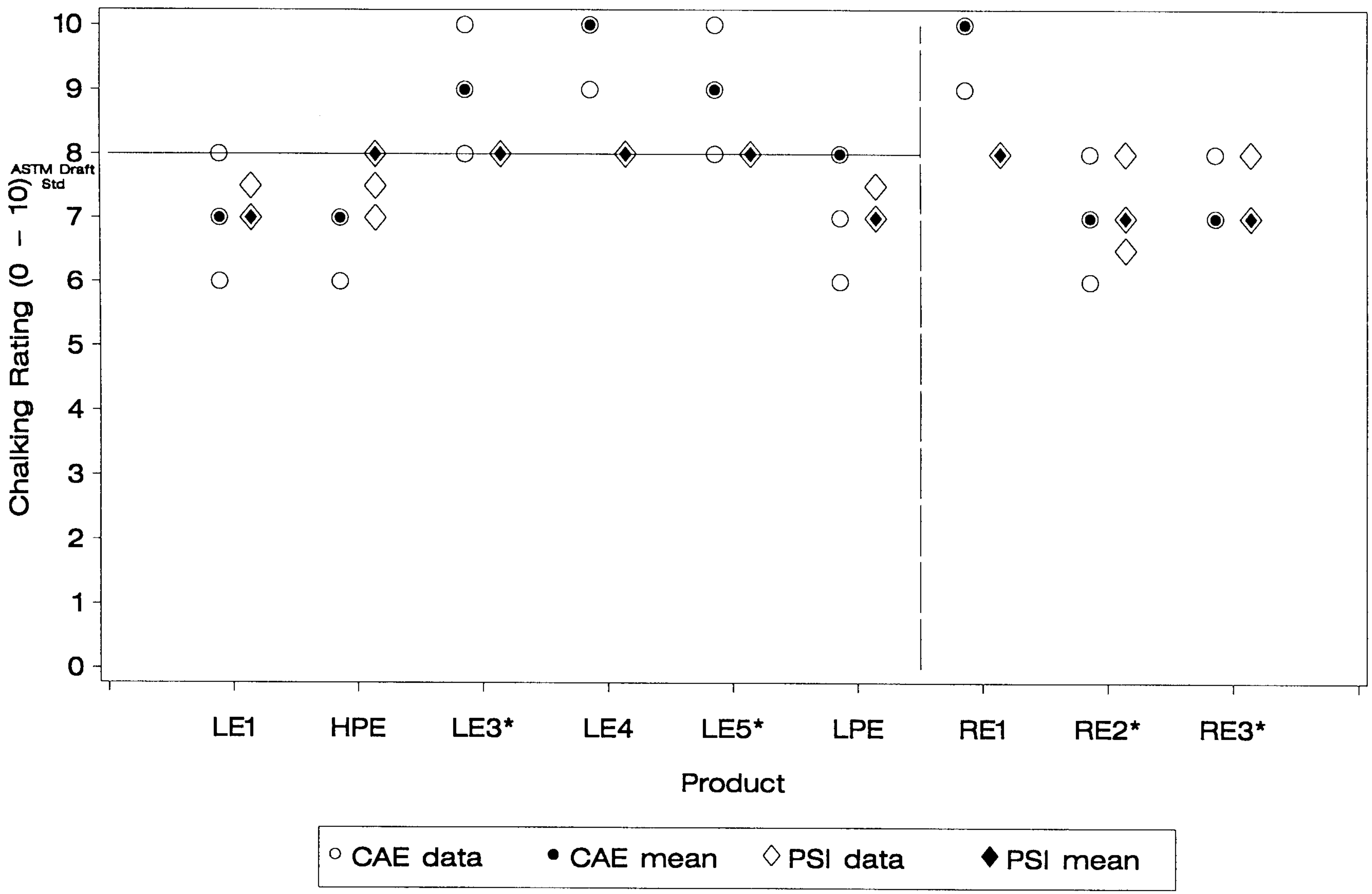
- **No significant variability between the results for replicate encapsulant products was found at either testing laboratory (Table 13).**

- **For tests performed at both laboratories, the average chalking rating for liquid encapsulants was statistically significantly higher (i.e., less chalking was observed),**

but not practically higher, than the average rating for standard exterior paints (Table 13).

- **For the liquid exterior products, results from the multiple comparisons analysis suggest no clear**

Figure 24
Chalking Results for Weathered Panels



distinction among different types of products. However, the standard exterior paints (LPE and HPE) and the hybrid latex encapsulant (LE1) experienced somewhat more chalking than the other three liquid products (Table 20).

Summary of Results for Chalking Ratings

The reinforced encapsulants, liquid encapsulants, and paints all exhibited similar average ratings; and no clear grouping was observed in the test results between various types of products. Also, results from this study indicate that while some differences observed for the chalking test were statistically significant, they may not be practically significant. For example, most of the significant differences found were on the order of 1 or 2 rating points.

4.13 PENCIL HARDNESS

Film hardness was determined by the pencil test for all 18 products both before and after water immersion. Special calibrated pencils were moved across each sample surface at an angle specified by the ASTM test method and then progressively softer pencils were used until a pencil was found that did not cut (gouge) the sample surface. The number of this pencil was then recorded as the end point. Two locations were tested on each panel and reported.

Determination of film hardness by the pencil test is not currently proposed as a test to evaluate performance for encapsulants. It was included in this study to provide additional information about the effect of the 24-hour water immersion on the surface hardness of the products. Identification of the end point is subjective and can vary from one technician to another. Therefore, hardness by the pencil test may have poor interlaboratory repeatability and reproducibility.

Results for Unexposed Panels

The pencil hardness results for unexposed panels are presented in Figure 25 for all 18 products and both testing laboratories. As with the blistering data presented earlier, this figure shows both individual panel ratings and the mode (i.e., most frequently cited rating) for each product and laboratory. As shown in Table 11, data completeness was good for CAE and poor for PSI. CAE had one panel (two measurements) for the acrylic and polyester product RE3 that delaminated prior to testing. PSI on the other hand misunderstood the study design, thinking they were only to test panels after water immersion and not before. Therefore, they were only able to complete 36 tests on a small number of unexposed and unused panels they still had near the end of the study.

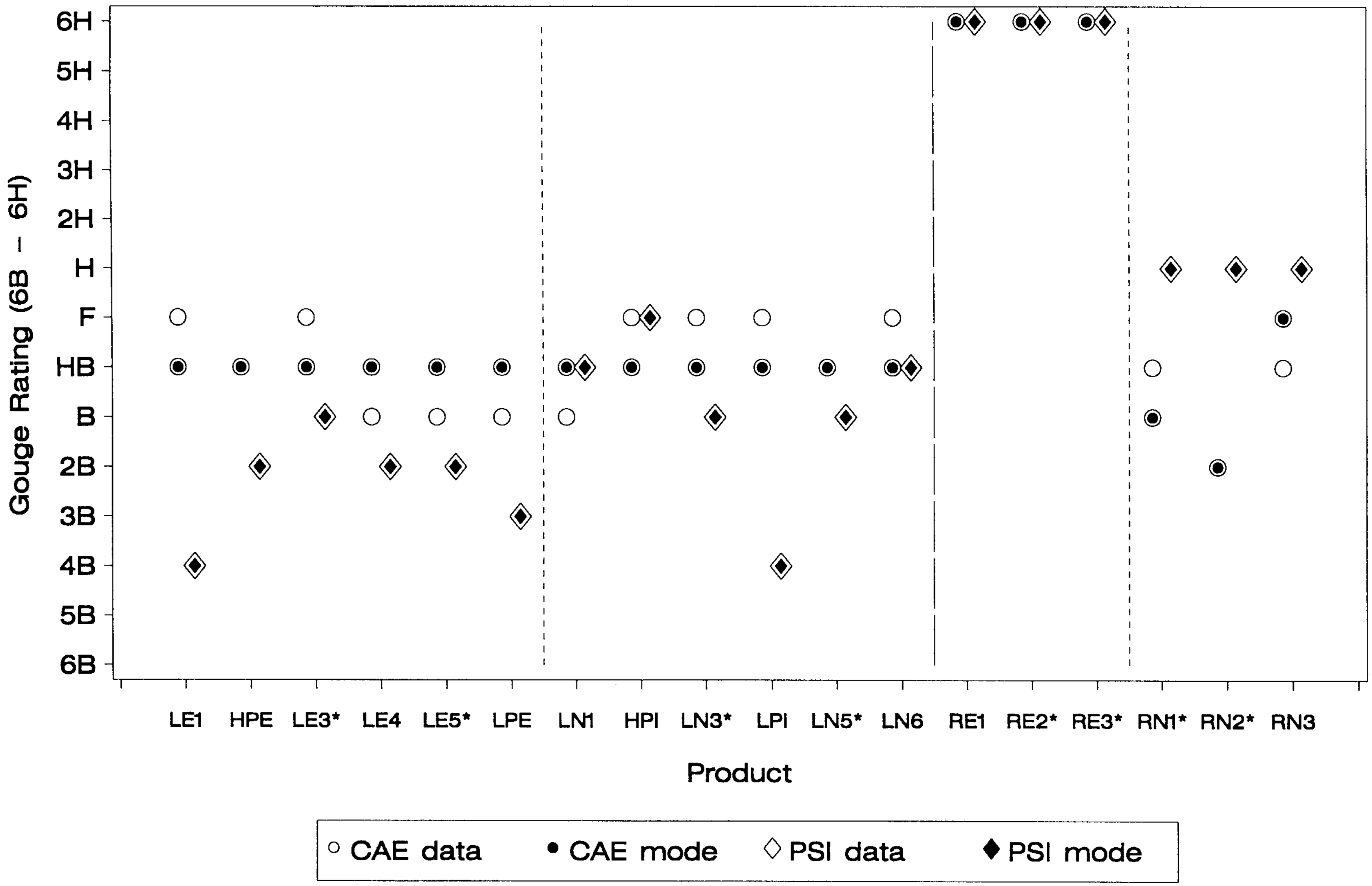
Prior to statistical analysis the pencil hardness ratings shown in Figure 25 were recoded to an increasing numerical scale of 0-13 where the values 0 and 6B represent the softest coatings, and the values 13 and 6H represent the hardest coatings. Tables 12, 13, and 21 present results from the statistical analysis of the pencil hardness data which can be summarized as follows:

- **Table 12 indicates that on average the reinforced coatings (9 rating) were harder than the liquid coatings (6 rating), although this difference was mostly attributable to the hardness of the reinforced exterior products (all panels had the maximum rating of 13). Also, the hardness ratings were reasonably consistent between the two laboratories (Table 13).**

- **Differences between the hardness ratings of replicate encapsulant products were generally found to be statistically significant, but not practically significant, with average differences only up to 3 being observed (Table 13).**

- **No practically significant difference was found between the average pencil hardness of liquid encapsulants and paints.**

Figure 25
Pencil Hardness Results for Unexposed Panels



- The only noteworthy trend seen in the multiple comparisons results for both laboratories was that the reinforced exterior products were significantly harder than the reinforced interior products (Table 21).

Immersed Panels

Pencil hardness data for the immersed panels are presented in Figures 26 and 27 corresponding to readings taken approximately 10-20 minutes versus 120 minutes after removal from the water, respectively. Data completeness was quite good for this data set. PSI reported all 156 measurements that were planned, while CAE had problems with only two panels (Table 11). One panel (two readings) for product LN4 was damaged while performing the 10-minute pencil hardness test, and could not be used for the subsequent 120-minute test. Also, one panel (two readings) for the acrylic and polyester reinforced product RE3 delaminated prior to water immersion making further testing impossible.

The following points highlight the results of the pencil hardness testing which are also summarized in Tables 12, 13, and 21:

- Both the liquid and reinforced coatings experienced a loss of hardness at both 10 minutes and 120 minutes after water immersion in comparison with unexposed panels (Table 12). It should be noted, however, that the loss in hardness was less for the reinforced products in general, and that the reinforced exterior products experienced no loss in hardness (Figures 25, 26, and 27).

- Differences in hardness after immersion between replicate encapsulant products were generally not found to be significant.

- Pencil hardness after immersion for liquid encapsulants was not found to be significantly different from that for paints (Table 13).

- The multiple comparisons analysis found that the hardest liquid products after immersion were generally the high-quality exterior paint (HPE) and the acrylic exterior

encapsulant (LE4); while the hardest reinforced products after immersion were the exterior products.

Table 21. Results of Multiple Pairwise Comparisons for Pencil Hardness Testing

Test Type	Liquid Products												Reinforced Products					
Pencil Hardness--Unexposed Panels--CAE																		
Product	LE1	LPI	LE3*	LN6	LN3*	HPI	LN5*	HPE	LE4	LE5*	LN1	LPE	RE1	RE2*	RE3*	RN3	RN1*	RN2*
Mean (0-13 rating)	6	6	6	6	6	6	6	6	6	6	6	6	13	13	13	7	5	4
Group A	A	A	A	A	A	A	A	A	A				A	A	A			
Group B							B	B	B	B	B	B				B		
Group C																	C	
Group D																		D
Pencil Hardness--Unexposed Panels--PSI																		
Product	HPI	LN1	LN6	LN3*	LE3*	LN5*	HPE	LE4	LE5*	LPE	LE1	LPI	RE1	RE2*	RE3*	RN1*	RN2*	RN3
Mean (0-13 rating)	7	6	6	5	5	5	4	4	4	3	2	2	13	13	13	8	8	7
Group A	A												A	A	A			
Group B		B	B													B	B	B
Group C				C	C	C												
Group D							D	D	D									
Group E									E	E								
Group F											F	F						
Pencil Hardness--10 min. After Immersion--CAE																		
Product	No analysis--no variation among panels												RE1	RE2*	RE3*	RN3	RN2*	RN1*
Mean (0-13 rating)													13	13	13	5	0	0
Group A													A	A	A			
Group B																B		
Group C																	C	C
Pencil Hardness--10 min. After Immersion--PSI																		
Product	LE4	HPE	LE5*	HPI	LN3*	LPI	LE3*	LN1	LE1	LPE	LN5*	LN6	RE1	RE2*	RE3*	RN3	RN2*	RN1
Mean (0-13 rating)	4	2	1	1	0	0	0	0	0	0	0	0	13	13	13	9	0	0
Group A	A	A											A	A	A			
Group B		B	B	B	B	B	B	B	B	B	B	B				B		
Group C																	C	C

::

Table 21. Continued

Test Type	Liquid Products												Reinforced Products
Pencil Hardness--120 min. After Immersion--CAE													
Product	HPE	LE5*	LE1	HPI	LN1	LPE	LE4	LN6	LE3*	LN3*	LN5*	LPI	No analysis--no variation among panels
Mean (0-10 rating)	5	4	3	3	2	2	2	2	1	1	0	0	
Group A	A	A	A	A	A	A	A	A					
Group B		B	B	B	B	B	B	B	B	B	B	B	
Pencil Hardness--120 min. After Immersion--PSI													
Product	LE4	HPE	LN1	HPI	LPE	LPI	LN5*	LE1	LE5*	LN3*	LE3*	LN6	No analysis--no variation among panels
Mean (0-13 rating)	7	5	2	2	1	1	1	0	0	0	0	0	
Group A	A	A											
Group B		B	B	B	B	B	B	B	B	B	B	B	

Figure 26
Pencil Hardness Results for Immersed (10 minute dry) Panels

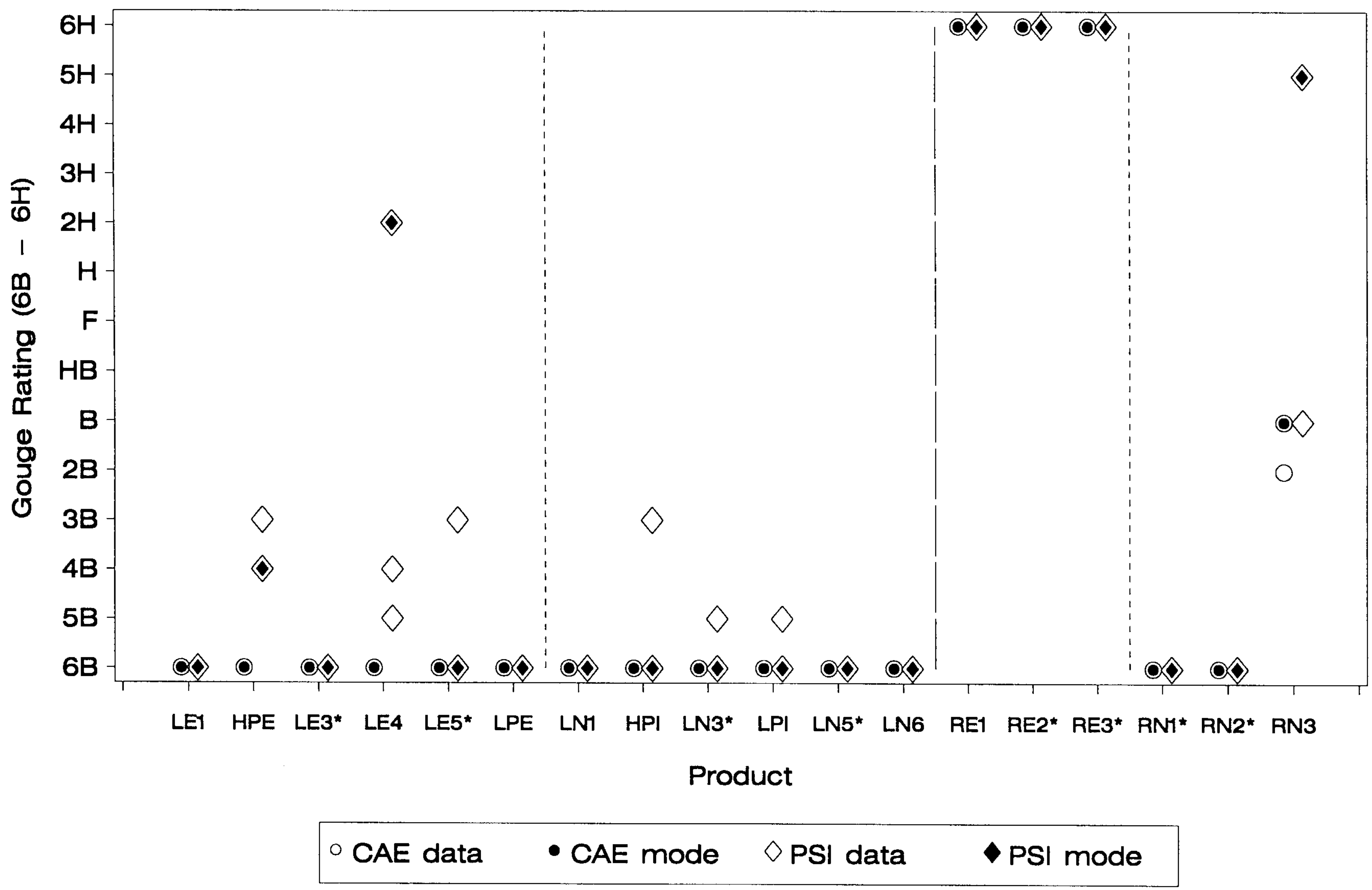
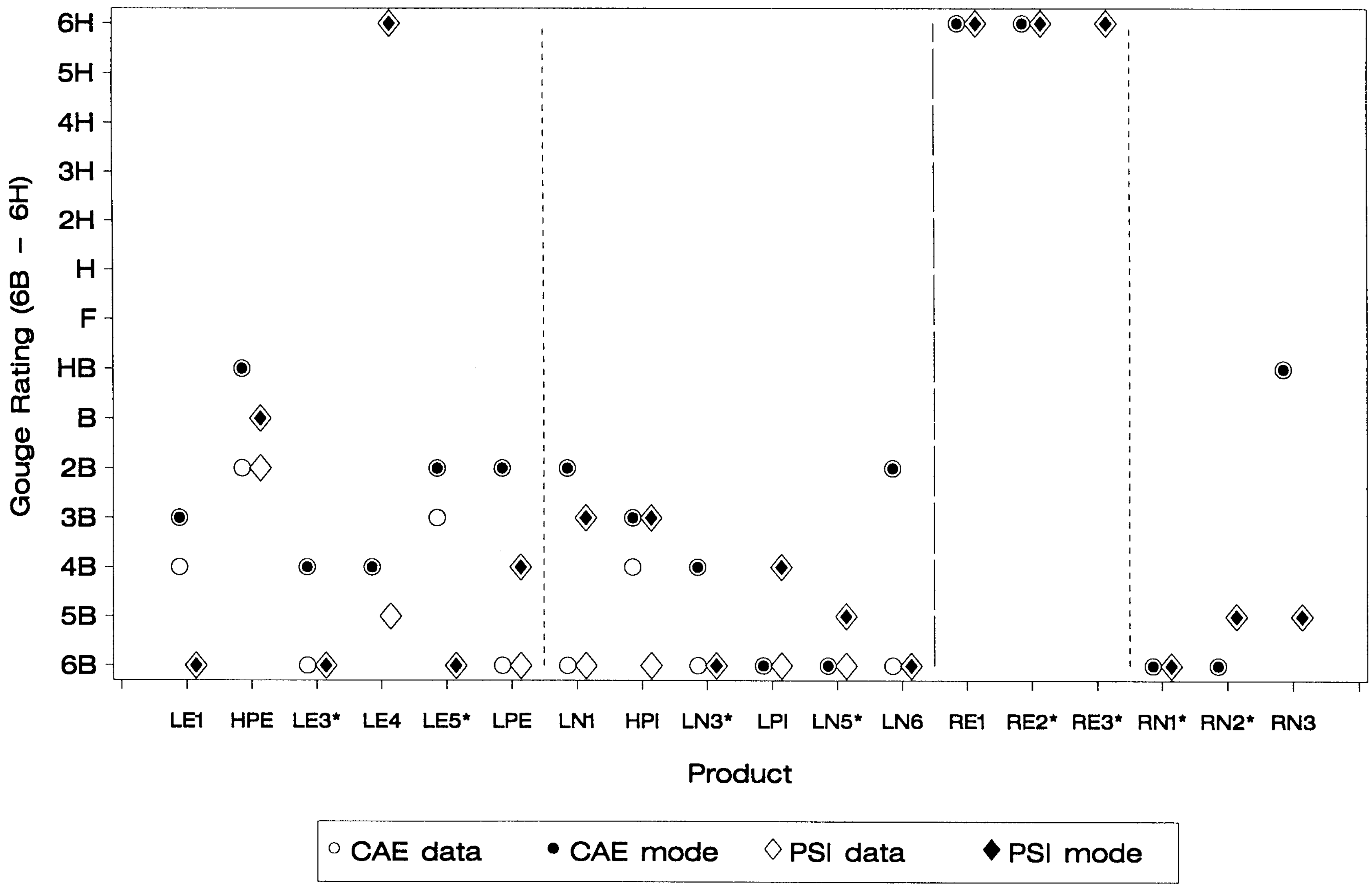


Figure 27
Pencil Hardness Results for Immersed (120 minute dry) Panels



Summary of Pencil Hardness Results

Results from this study indicate that the pencil hardness test can probably distinguish the exterior reinforced encapsulant products from other coatings, but not differences among other types of products. After water immersion, all products except the reinforced exterior encapsulants experienced a substantial loss of hardness.

5.0 QUALITY ASSURANCE

This section summarizes the quality assurance steps that were taken throughout the study to ensure the quality of the test results. Important elements of the study design related to quality assurance are described first, followed by a summary of the approach and results from the three different quality assurance audits that were conducted at each laboratory.

5.1 METHODS EMPLOYED

Initial planning for this study involved the writing of a Quality Assurance Project Plan (QAPjP). The QAPjP (1) described in detail the study design, sample collection procedures, analysis and measurement methods, data processing and statistical analysis procedures, and planned quality assurance audits. Copies of internal quality assurance plans from each of the testing laboratories were also obtained and included as part of the QAPjP. Before any actual testing occurred, the QAPjP was submitted for EPA approval, and then copies were distributed to the designated Quality Assurance Officers at each of the laboratories. In addition to the study design previously discussed in Chapter 2, the QAPjP outlined specific procedures to ensure the quality of the study data. These procedures are briefly described discussed in the following paragraphs.

Sample products used for testing were purchased in regular commercial containers as supplied by the manufacturers. The containers were cleared of commercial identifying marks and labeled with three-character Product ID codes corresponding to each of the 18 products selected for testing. The products were then shipped to each of the laboratories along with a Product Identification Form to trace the exact quantities transferred. Application instructions for each product were also written based upon recommendations from the manufacturers and were shipped with the products. All products were protected from environmental extremes during shipment and storage as directed by the manufacturers.

Sample panels were prepared by the laboratories based on the application method, film thickness, and dry/cure time specified in the instructions for each product. All panels were permanently labeled with an identification code comprised of the Product ID and a unique sample number. The entire sample preparation process, including equipment used and procedures followed, was documented in such a way that the panel preparation process could be duplicated in the future.

Equipment used to measure data was calibrated with traceability to national reference standards. Calibration procedures were performed before and after each equipment use, and between measurements as needed for each particular instrument. The actual calibration schedule followed during testing was documented by each laboratory.

In order to protect against potential biases introduced during testing by various instruments, testing days, and technicians, all tests were performed in a randomized order. Randomized testing schemes were prepared for each of the test types and were given to the laboratories. These schemes ensured that the panels prepared with each individual product were tested in a different randomized order for each test type and each replicate panel, with each laboratory following the same order.

All study data were examined for accuracy through a series of checks. Electronic data files were generated by each laboratory before transfer for statistical analysis. Prior to transfer, each laboratory performed a 100% check of its data files to confirm that the data were consistent with the test results recorded in the laboratory books used during testing. Extensive visual inspections of the data were also conducted prior to performing any statistical analysis. Obvious outliers, incomplete test results, and other discrepancies found in the data were reported to the laboratories for correction or explanation. Finally, a data audit was designed to compare 5-10% of the data in the laboratory notebooks with the final SAS® datasets used in the statistical analysis.

5.2 AUDIT RESULTS

To ensure data quality within the project, each testing laboratory was subjected to three separate quality assurance audits -- a system, performance, and data audit. These audits, conducted by the Quality Assurance Unit of the statistical analysis contractor, were in addition to the routine quality control checks and procedures performed at each laboratory.

System Audit

The system audit was conducted via an on-site inspection at each laboratory prior to testing to ensure that the sample handling, testing, data collection, and quality control procedures were adequate to meet the data quality objectives of the program. Areas examined in the audit included company organization and personnel, laboratory facilities, operations, and equipment. The system audit at PSI was performed on February 1, 1994, and the audit of CAE occurred on February 2, 1994.

The system audit at PSI determined that their quality assurance and quality control procedures, personnel qualifications, equipment suitability and availability, and facility parameters were all adequate for performance of the study, with the exception of four specific recommendations. PSI was formally asked to resolve these issues on February 7, 1994, and a response from PSI agreeing to implement changes was received on February 23, 1994. The issues of concern followed by the steps that PSI took to resolve them are listed below.

- A management review of Personnel Training Forms for Test Procedures and Standards needed to be completed to insure that technical staff assigned to the study were familiar with current standards, and that company training requirements shown in the Quality Assurance Manual were in compliance. PSI indicated that they were currently performing a review to update their Personnel Training Forms. They also were reviewing the applicable ASTM Methods and signing-off on the forms.

- Moderate to severe housekeeping and cleanliness problems were noted throughout the facility. PSI stated that cleaning would be performed on a daily basis, and that they would take steps to assure a clean environment, including air and working surfaces.

- Facility plans to address necessary spatial requirements for adequate test panel preparation and drying needed to be documented. PSI stated that the inner laboratory area would be used for the sample preparation. They also obtained a system of shelves that could be placed in the lab for drying the panels.

- Equipment was lacking or insufficient with regards to the weathering chamber, actual ASTM photographic reference standards for ASTM D 714, enough dollies to use for pull adhesion with the water immersion test, and available hood space. The requirement to perform and document daily balance calibration checks with a 2x standard weight bracket was also mentioned. PSI arranged to purchase a second weathering chamber and a set of ASTM D 714 photographic standards; planned to clean and reuse their current supply of dollies (additional dollies were available from a local supplier if needed); planned to efficiently utilize their hood space; and planned to check the analytical balances with standard calibration weights on testing days.

The quality assurance and quality control procedures, personnel qualifications, equipment suitability and availability, and facility parameters for CAE were examined during their system audit, and were all found to be adequate for performance of the study, with the exception of four specific recommendations. CAE was formally asked to resolve these issues on February 8, 1994, and a letter from CAE responding to these issues was received on February 15, 1994. The issues of concern followed by the steps that CAE took to resolve them are listed below.

- Additional QA staff were needed to monitor the QA/QC activities for the study, as well as meet the facility QA objectives. CAE hired an additional staff member for their Quality Assurance Section to assist with the QA tasks for this study and to update their Quality Assurance Manual.

- Files containing staff capability, experience, and training were found to be incomplete in some cases. CAE assigned their Personnel Director to assemble information concerning staff capability, experience, on-the-job training, and vendor training into a single Personnel Qualifications File.

- Only those ASTM Method versions referenced in the study QAPjP were applicable to this program even though CAE possessed more recent versions of some of the methods. CAE advised their staff members working on the study to use only the QAPjP-referenced ASTM Method versions.

- It was requested that the daily balance calibration check with a 2x standard weight bracket on days of use be documented in the study files. CAE included in their test protocol that a daily balance calibration check with a 2x standard weight bracket be conducted and documented in program notebooks.

Performance Audit

The performance audit was conducted via an on-site inspection to ensure that testing, data collection, and quality control procedures were being properly implemented in accordance with the study QAPjP. Performance audits were scheduled to be conducted after approximately 25% of the required tests had been completed so that a significant amount of data had already been collected, but yet the majority of tests were still to be run. In this way any performance concerns which were discovered could be addressed and corrected before the majority of the data were collected.

Areas examined during the audit included training and capabilities of laboratory staff; availability and condition of laboratory facilities; availability, maintenance, and calibration of the testing equipment; and adherence to standard sample handling, testing, data collection, and quality control procedures. Implementation of recommendations made during the system audit were also discussed with each laboratory as part of the performance audit. The performance audit at CAE was conducted on April 6, 1994, while the performance audit at PSI was delayed until May 13, 1994, because of schedule difficulties they encountered while preparing the sample panels.

During the performance audit at CAE the scrub resistance test and panel exposure in the weathering chamber were observed. With the exception of minor items, CAE appeared to be performing the tests within, or exceeding, compliance aspects stipulated in the QAPjP. CAE was notified of the following exceptions in a letter dated April 13, 1994.

- Lab records needed to be expanded to include descriptions of all mixing and sub-sampling steps performed prior to panel application; gage designations, calibration procedures, and adherence to test method citation needed to be included in the Dry Film Thickness record book; and the source and type of silica used for the Abrasive Scrub Media needed to be noted in the Scrub Resistance record book.

- Immediate resolution to blocking and sticking of prepared sample panels needed to be addressed, with any damage noted on these panels included in the study records. A thorough quality control check of panel identification also needed to be performed and documented.

- Work should continue towards the improvement of personnel training and experience records and Standard Operating Procedures and maintenance records. It was noted that the new Quality Assurance staff member was currently being trained to assist in these efforts.

The performance audit at PSI took place while laboratory staff were conducting the scrub resistance test. Audit personnel observed that PSI was performing the tests as required and in accordance with the QAPjP. Specific items that were recommended to PSI based on the performance audit, as well as incomplete implementation of the system audit recommendations, are listed below. These issues were discussed with laboratory officials during the performance audit and were documented in a letter to PSI dated June 8, 1994.

- Replacement of the facility QA Supervisor was needed to insure a totally independent QA/QC function within the facility. The current design of district managers providing their own QA/QC oversight leads to a possible conflict of interest.

- Continued improvement in the cleanliness and organization of the laboratory work area was encouraged.

- Location of the third set of MSDS sheets shipped with the products needed to be determined so that they could be returned at study completion.

- Improved documentation in laboratory records was needed regarding test panel accountability, test panel preparation and preconditioning, daily calibration checks of balances, and any other experimental details required to reconstruct the study activities conducted at PSI.

- Verification of the Weatherometer time and temperature readings needed to be added to the study records.

- Laboratory staff needed to be reminded to use ink when recording test data and to make study records as complete and legible as possible.

Data Audit

The data audit was conducted via a comparison of original laboratory data records against data listings created from the project database to ensure that test data were accurately transferred and that no systematic errors were introduced to the data throughout the testing, data collection, and reporting steps of the study. Since both laboratories were required to perform a 100% check of their data before transmitting it, the data audit was designed to verify only 10% of the data generated by each laboratory. However, plans were made to subject the remaining portion of the data to audit if serious discrepancies were uncovered in the verification process. The data audit took place during April and May of 1995.

A total of 39 panels from each laboratory were chosen by a random method for the data audit. The selection of these panels was designed to ensure that panels for all test types and all encapsulant products were included in the audit. Data for these panels were tracked from test substance preparation and application through electronically transmitted test results.

Selection of the data audit panels was designed to ensure that panels for all test types and all products were included in the data audit. For this reason, the number of audit panels from each test type was determined proportionately to the planned total number of panels for that test type. Table 22 shows the breakdown by test type of planned total number of panels (also expressed as a percentage of total panels), and the corresponding number of panels to audit. The number of panels to audit was calculated by multiplying the planned percentage of panels by 39 (the total number of panels to be audited) and rounding up to a minimum of 1 panel when necessary.

After determining the number of panels to be audited for each test type, two randomized lists were generated to determine the actual panels to be audited. The first list contained a randomized ordering of the 18 encapsulant products. This sequence was repeated three times so that all encapsulant products would be selected at least twice for the data audit. The second list contained a set of randomly chosen replicate panel numbers for every test type. Each of these numbers was independently chosen based on the number of replicate panels tested for the test type, and the size of each set corresponded to the number of panels to be audited for each test type.

Actual panel selection was identical for both testing laboratories. Beginning with the first test type and continuing through each of the 13 test types defined in Table 22, the appropriate numbers of products were sequentially selected from the randomized product list. The specific replicate panels for these products were then taken from the second list. When necessary, a product was temporarily skipped on the product list if it was not one of the products tested for the current test type (e.g., LN1 was not tested after weathering, reinforced products were not tested for tape adhesion). The skipped product was then included for the next possible test type.

The selection of panels for two of the test types had to be modified slightly from the approach described above:

- Test Type 2 (Impact Resistance) - There were no individual panel results for this test. The final test result is based on at least 15 hits performed on all replicate panels. For this reason all replicate panels were included in the data audit.

TABLE 22. SUMMARY OF DATA AUDIT PANELS AND PERFORMANCE TESTS

Test Type	Tests Performed	Planned Total No. of Panels (% of All Panels)	No. of Panels to Audit	Panels Selected for Audit	
				CAE	PSI
1	Dry Film Thickness, Scrub Resistance	54 (10.3%)	4	AJA 235 LE4 AIB 210 LE3 AAA 001 LN1 BEA 589 RN1	LE4-1 LE3-2 LN1-1 RN1-3
2	Dry Film Thickness, Impact Resistance	72 (13.7%)	5*	LE6 RN3 LN4 LN6 RN2	LE6 RN3 LN4 LN6 RN2
3	Dry Film Thickness, Flexibility	54 (10.3%)	4	ABH 034 LN2 AKI 269 LE5 BHH 665 RE1 ACJ 062 LN3	LN2-4 LE5-8 RE1-7 LN3-6
4	Dry Film Thickness, Dry Abrasion	36 (6.9%)	3	BJL 715 RE3 AEK 115 LN5 AGK 167 LE1	RE3-23 LN5-15 LE1-25
5	Dry Film Thickness, Adhesion-Tape	12 (2.3%)	1**	AHM 195 LE2	LE2-13
6	Dry Film Thickness, Adhesion-Pull	54 (10.3%)	4	BIO 695 RE2 AJO 249 LE4 AIO 223 LE3 AAO 015 LN1	RE2-11 LE4-11 LE3-11 LN1-8
7	Dry Film Thickness, Viscoelastic Properties	90 (17.1%)	6	AYC 519 RN1 AXA 505 LE6 BAG 547 RN3 APE 413 LN4 ARI 441 LN6 AZI 537 RN2	RN1-2 LE6-10 RN3-7 LN4-4 LN6-4 RN2-8
8	Dry Film Thickness, Water Immersion, Blistering, Pencil Hardness, Adhesion-Tape	12 (2.3%)	1**	ABT 046 LN2[+] ABV 048 LN2[++]	LN2-13
9	Dry Film Thickness, Water Immersion, Blistering, Pencil Hardness, Adhesion-Pull	54 (10.3%)	4	AKU 281 LE5 BHM 670 RE1 ACS 071 LN3 BJM 716 RE3	LE5-16 RE1-13 LN3-13 RE3-13

TABLE 22. (Continued)

Test Type	Tests Performed	Planned Total No. of Panels (% of All Panels)	No. of Panels to Audit	Panels Selected for Audit	
				CAE	PSI
10	Dry Film Thickness, Weathering, Blistering, Chalking, Adhesion-Tape	6 (1.1%)	1**	AGA 313 LE1	LE1-24
11	Dry Film Thickness, Weathering, Blistering, Chalking, Adhesion-Pull	27 (5.1%)	2	AHD 326 LE2 BLC 740 RE2	LE2-23 RE2-21
12	Dry Film Thickness, Weathering, Blistering, Chalking, Flexibility	27 (5.1%)	2	AJE 347 LE4 AIG 339 LE3	LE4-18 LE3-20
13	Dry Film Thickness, Weathering, Blistering, Chalking, Scrub Resistance	27 (5.1%)	2	ALI 371 LE6 BKH 735 RE1	LE6-5 RE1-4
Total		525 (100%)	39		

* All panels audited for each of the 5 products selected.
**Three results to be audited for each panel.
+ Panel used for blistering and pencil hardness tests.
++Panel used for adhesion-tape test.

Tab 22

- Test Type 8 (Immersed Tape-Adhesion, etc.) - Instead of performing the Tape-Adhesion, Blistering, and Pencil Hardness tests on the same test panel, CAE used separate panels to perform the Tape-Adhesion test than they used for the Blistering and Pencil Hardness tests. In order to include all types of test data, the appropriate replicate panel was selected for the Tape-Adhesion test and the same replicate panel number was used to select the Blistering and Pencil Hardness panel.

Significant audit findings for CAE are listed below. A letter was sent to CAE on June 19, 1995, asking for clarification or explanation for each of the items listed. Other minor discrepancies are detailed in the Data Audit Report (submitted to EPA in July 1995).

- Physical Verification of Audit Panels and Films - Two test panels and all six viscoelastic films could not be located for the audit.

- Unexposed Scrub Resistance - Dry film thicknesses for all four panels were not in agreement with lab record books.

- Impact Resistance - Data results reported for some individual panels appeared to be combinations of hits from multiple panels.

- Unexposed Pull Adhesion - Data reported for failure type (adhesive vs. cohesive) were opposite of those listed in lab record books for all four panels.

- Pull Adhesion After Water Immersion - Data reported for failure type (adhesive vs. cohesive) were opposite of those listed in lab record books for all three panels.

- Tape adhesion After Weathering - Dry film thicknesses for both panels were not in agreement with lab record books.

- Pull Adhesion After Weathering - Dry film thicknesses for both panels were not in agreement with lab record books. Data reported for failure type (adhesive vs. cohesive) were opposite of those listed in lab record books for both panels.

- Flexibility After Weathering - Dry film thicknesses for both panels were not in agreement with lab record books.

- **Scrub Resistance After Weathering** - Dry film thicknesses for both panels were not in agreement with lab record books.

In response to the data audit questions, CAE rechecked their data and procedures, and on July 20, 1995 submitted a letter with explanations for each question. After considering these responses, it was determined that all data in question were correct as reported earlier, and that no changes were required to the project data base.

Serious audit findings for PSI included a lack of documentation as to when the water immersion and weathering steps were performed. In addition, listed below are audit findings for specific tests. A letter dated June 19, 1995, was sent to PSI asking for clarification or explanation for each of the items listed, as well as the lack of water immersion and weathering documentation. Other minor discrepancies are detailed in the Data Audit Report (submitted to EPA in July 1995).

- **Impact Resistance** - The reported heights for one of the panels did not agree with the lab record books.

- **Tape Adhesion After Water Immersion** - Only one pencil reading was recorded for the one audited panel.

- **Pull Adhesion After Water Immersion** - Only one pencil reading was recorded for each of the four panels.

- **Tape adhesion After Weathering** - The chalking result reported for the one audited panel did not agree with the lab record books.

- **Flexibility After Weathering** - A dry film thickness reading for one panel was not in agreement with lab record books.

In response to the data audit questions, PSI rechecked their data and procedures, and on July 24, 1995 submitted a letter with explanations and further information for each question. The PSI response led to minor changes to one coating thickness

measurement listed in the Appendix and to one point shown on Figure 13 for the impact resistance test results. However, in both cases these changes were so minor that they did not require any changes to be made to the project data base.

6.0 RECOMMENDATIONS

The results of this comparative study of 12 encapsulant products and four commercial paints can be useful for assessing the merits of the individual tests in distinguishing among the products tested. The results can provide guidance for establishing realistic levels of performance for products of this type by providing actual data on the performance of a number of commercial products as measured in more than one laboratory by more than one operator. However, there are several testing issues that should be considered in the process of improving the test methods and selecting numerical values for minimum performance standards.

1. All of the tests performed in this study, with the exception of the scrub resistance test and viscoelastic tests, were conducted using standard metal panels. However, the adhesion of some encapsulants to metal panels is questionable. These products are not formatted specifically for metal adhesion. Non-metallic substrates are more common in the residential settings for which these encapsulants were designed. Performance testing on non-metallic substrates may provide a more realistic indication of product performance that can be expected in service. The feasibility of performing these ASTM tests, or other tests, on non-metallic substrates should be investigated. However, alternate substrates may present their own set of challenges. Selection of alternate substrates or substrate treatments such as abrasion or primers should be based on solid physical data.

2. Adhesion is probably one of the most important physical properties that an encapsulant must possess if it is to perform well in the field. Results from this study indicated several difficulties with the tape and pull adhesion tests used to assess this property. Reproducibility of this test is affected by tape

and adhesive variations, as well as by operator techniques. The tape test showed a lack of sensitivity to detect differences among products, and it could not be performed on the reinforced encapsulants. The pull adhesion test indicated concerns with adhesion to the tin-plated steel panel, the instrumentation used, the adhesive used to fasten the dollies to the panels, scoring around the dollies for the reinforced products, and use of the relatively thin 0.01 inch test panel. Investigation into solutions to these concerns with the current tape and pull adhesion tests is recommended, as well as consideration of alternative tests that may be available.

3. Variation in system thickness among panels for the same product can in some cases introduce significant variations to the subsequent performance testing results. In this pilot study, target system thickness ranges were based on product literature recommendations for field application. These recommendations were usually based on spray, roll, or brush application on vertical surfaces. The product manufacturers have experience applying these products both in the field and in the laboratory. Therefore, they should be able to provide tighter target ranges for each multi-coat and reinforced product for test panel preparation by drawdown. With some additional input from the manufacturers, testing laboratories should be able to decrease the intralaboratory and interlaboratory variability of test panels for each multi-coat and reinforced product.

4. ASTM E06.23.30 is considering a combination of tensile strength and elongation to define three liquid product groups. Changes in these properties after exposure to temperature, time, and weathering protocols in the laboratory might be quite useful for understanding and predicting field service of the coatings. However, determination of these properties is not as rapid and easy to perform as some of the older, more widely used,

"practical" tests such as abrasion resistance, impact resistance, flexibility, and hardness. Also, additional time and laboratory expertise is needed to make good free films. Comparative testing after exposure to weathering and other exposure conditions may be difficult or expensive to implement for performance testing. However, the potential use of additional viscoelastic elasticity testing after exposure should be investigated.

5. Testing in this pilot study indicated significant variability in some cases between replicate encapsulant products, that is, between results for two batches of panels prepared with two different samples of the same product. Therefore, when batch-to-batch variability is large, performance testing decisions should not be based on test results from a single product sample, but instead should be determined from testing a number of different batches of the product.

6. Many of the tests performed in this study may give their most useful information as comparative tests, particularly when test samples are prepared at the same time to control variables such as application method, sample panel type, film thickness, cure/dry time, test conditions (temperature and relative humidity), and multiple operators or instruments. Tests such as scrub resistance, dry abrasion resistance, impact resistance, tape adhesion, and pull adhesion can provide valuable information about the relative performance of two or more coatings evaluated at the same time in the same laboratory. Therefore, it may be useful to set some performance standards based on ranked results among products rather than actual numerical standards. In this approach, a known standard coating(s) would be required to serve as a benchmark for the test results.

7. Although evaluation of ten potential test protocols was conducted in this study, there are a number of other performance

properties, suggested by ASTM E06.23.30 and others, that might also be investigated. For example, chemical resistance, bridging of substrate cracking, and lead accessibility are other properties for which testing results are not yet available to ASTM, although they are perhaps being generated currently by other groups.

8. Performance testing in the laboratory is relatively controlled and reproducible in comparison with performance that might be experienced by the same products in natural residential environments. And it is this performance in service in the field that is critical to the effective use of encapsulants. There is currently little, if any, information which directly correlates laboratory performance testing results with field performance. This information should be collected and quantitatively analyzed. Of course, such an evaluation will require establishing performance tests that can be conducted in a residential setting and which adequately measure the true performance of encapsulants in the field.

7.0 REFERENCES

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2. American Society for Testing and Materials, 1994, "Standard Specification for Liquid Coating Encapsulation Products for Leaded Paint in Buildings", draft standard, ASTM, Philadelphia, PA.

3. American Society for Testing and Materials, 1994, "Standard Specification for Reinforced Liquid Coating Encapsulation Products for Leaded Paint in Buildings", working draft standard, ASTM, Philadelphia, PA.

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15. Supplementary Notes

16. Abstract (Limit 200 words)

The American Society for Testing and Materials (ASTM) Task Group E06.23.30 on Encapsulation of Leaded Paint is currently developing performance standards which can be used to approve encapsulants for use in residential environments; however, few data have been submitted upon which to base any standards. Recognizing this critical need for data, the U.S. Department of Housing and Urban Development and the U.S. Environmental Protection Agency have begun evaluating currently available tests. Since the viability of many test methods for use with encapsulants is not yet known, the overall objective of this study was to evaluate the appropriateness of standard ASTM test protocols for assessing the performance characteristics of encapsulants.

The study was intended to collect data to help determine the feasibility of a battery of test protocols using both liquid coatings and reinforced liquid coatings; provide information to support the assessment of existing draft minimum performance standards; and assess the variability of these test methods between two laboratories and within a single laboratory. The study results have been analyzed at two levels: a qualitative evaluation of the feasibility of conducting these test on these new encapsulants, and a quantitative statistical analysis to assess variability in the test data.

17. Document Analysis

a. Descriptors

Lead, Lead-Based Paint, Lead-Based Paint Encapsulants, Performance Testing, Statistical Analysis

b. Identifiers/Open-Ended Terms

Tape Adhesion, Pull Adhesion, Scrub Resistance, Flexibility, Impact Resistance, Dry Abrasion Resistance, Viscoelastic Properties, Blistering, Chalking, Pencil Harness, Weathering, Water Immersion

c. COSATI Field/Group

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APPENDIX

DETAILED DATA LISTING FOR PILOT TESTING PROGRAM FOR PROTOCOLS FOR LEAD-BASED PAINT ENCAPSULANTS

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
1	CAE	LE1	AGA 157 LE1	6.5
2	CAE	LE1	AGA 313 LE1	6.0
3	CAE	LE1	AGB 158 LE1	6.2
4	CAE	LE1	AGB 314 LE1	5.8
5	CAE	LE1	AGC 159 LE1	6.3
6	CAE	LE1	AGC 315 LE1	5.5
7	CAE	LE1	AGD 160 LE1	6.1
8	CAE	LE1	AGD 316 LE1	5.2
9	CAE	LE1	AGE 161 LE1	5.8
10	CAE	LE1	AGE 317 LE1	5.3
11	CAE	LE1	AGF 162 LE1	6.3
12	CAE	LE1	AGF 318 LE1	5.3
13	CAE	LE1	AGG 163 LE1	6.6
14	CAE	LE1	AGG 319 LE1	5.7
15	CAE	LE1	AGH 164 LE1	5.7
16	CAE	LE1	AGH 320 LE1	6.1
17	CAE	LE1	AGI 165 LE1	5.9
18	CAE	LE1	AGI 321 LE1	6.3
19	CAE	LE1	AGJ 166 LE1	6.1
20	CAE	LE1	AGK 167 LE1	5.8
21	CAE	LE1	AGK 322 LE1	6.4
22	CAE	LE1	AGL 168 LE1	5.6
23	CAE	LE1	AGM 169 LE1	5.4
24	CAE	LE1	AGN 170 LE1	5.4
25	CAE	LE1	AGO 171 LE1	5.4
26	CAE	LE1	AGP 172 LE1	5.9
27	CAE	LE1	AGQ 173 LE1	6.0
28	CAE	LE1	AGR 174 LE1	5.6
29	CAE	LE1	AGS 175 LE1	5.7
30	CAE	LE1	AGT 176 LE1	5.8
31	CAE	LE1	AGU 177 LE1	5.9
32	CAE	LE1	AGX 180 LE1	6.1
33	CAE	LE1	ASA 445 LE1	6.0
34	CAE	LE1	ASB 446 LE1	6.2
35	CAE	LE1	ASC 447 LE1	5.6
36	CAE	LE1	ASD 448 LE1	6.1
37	CAE	LE1	ASE 449 LE1	6.9
38	CAE	LE1	ASH 452 LE1	6.5
39	CAE	LE1	ASI 453 LE1	5.9
40	CAE	LE1	ASJ 454 LE1	6.4
41	CAE	LE1	ASK 455 LE1	5.1
42	CAE	LE1	ASL 456 LE1	5.7
43	CAE	LE2	AHA 183 LE2	5.7
44	CAE	LE2	AHA 323 LE2	5.7
45	CAE	LE2	AHB 184 LE2	5.6
46	CAE	LE2	AHB 324 LE2	5.5
47	CAE	LE2	AHC 185 LE2	5.6
48	CAE	LE2	AHC 325 LE2	5.3
49	CAE	LE2	AHD 186 LE2	5.7
50	CAE	LE2	AHD 326 LE2	5.2
51	CAE	LE2	AHE 187 LE2	5.7
52	CAE	LE2	AHE 327 LE2	5.2
53	CAE	LE2	AHF 188 LE2	5.6
54	CAE	LE2	AHF 328 LE2	5.0
55	CAE	LE2	AHG 189 LE2	6.3
56	CAE	LE2	AHG 329 LE2	5.0
57	CAE	LE2	AHH 190 LE2	5.1
58	CAE	LE2	AHH 330 LE2	5.8
59	CAE	LE2	AHI 191 LE2	5.5
60	CAE	LE2	AHI 331 LE2	5.8
61	CAE	LE2	AHJ 192 LE2	5.5
62	CAE	LE2	AHK 193 LE2	6.8
63	CAE	LE2	AHK 332 LE2	5.7
64	CAE	LE2	AHL 194 LE2	5.5
65	CAE	LE2	AHM 195 LE2	5.2
66	CAE	LE2	AHN 196 LE2	5.2
67	CAE	LE2	AHO 197 LE2	5.4
68	CAE	LE2	AHP 198 LE2	5.6
69	CAE	LE2	AHQ 199 LE2	5.1
70	CAE	LE2	AHR 200 LE2	5.4
71	CAE	LE2	AHS 201 LE2	5.4
72	CAE	LE2	AHT 202 LE2	5.7
73	CAE	LE2	AHU 203 LE2	5.3
74	CAE	LE2	AHX 206 LE2	5.7
75	CAE	LE2	ATA 457 LE2	5.5
76	CAE	LE2	ATB 458 LE2	5.2

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
77	CAE	LE2	ATC 459 LE2	5.5
78	CAE	LE2	ATD 460 LE2	5.8
79	CAE	LE2	ATE 461 LE2	5.5
80	CAE	LE2	ATF 462 LE2	5.5
81	CAE	LE2	ATG 463 LE2	5.3
82	CAE	LE2	ATH 464 LE2	5.5
83	CAE	LE2	ATI 465 LE2	5.4
84	CAE	LE2	ATJ 466 LE2	5.5
85	CAE	LE3	AIA 209 LE3	6.5
86	CAE	LE3	AIA 333 LE3	7.5
87	CAE	LE3	AIB 210 LE3	6.5
88	CAE	LE3	AIB 334 LE3	7.2
89	CAE	LE3	AIC 211 LE3	6.4
90	CAE	LE3	AIC 335 LE3	6.7
91	CAE	LE3	AID 212 LE3	6.7
92	CAE	LE3	AID 336 LE3	6.5
93	CAE	LE3	AIE 213 LE3	6.8
94	CAE	LE3	AIE 337 LE3	6.3
95	CAE	LE3	AIF 214 LE3	7.0
96	CAE	LE3	AIF 338 LE3	6.5
97	CAE	LE3	AIG 215 LE3	7.1
98	CAE	LE3	AIG 339 LE3	6.8
99	CAE	LE3	AIH 216 LE3	6.7
100	CAE	LE3	AIH 340 LE3	7.8
101	CAE	LE3	AII 217 LE3	6.9
102	CAE	LE3	AII 341 LE3	7.5
103	CAE	LE3	AIJ 218 LE3	7.1
104	CAE	LE3	AIK 219 LE3	6.9
105	CAE	LE3	AIK 342 LE3	7.6
106	CAE	LE3	AIL 220 LE3	6.5
107	CAE	LE3	AIM 221 LE3	6.8
108	CAE	LE3	AIN 222 LE3	7.2
109	CAE	LE3	AIO 223 LE3	6.8
110	CAE	LE3	AIP 224 LE3	7.0
111	CAE	LE3	AIQ 225 LE3	6.9
112	CAE	LE3	AIR 226 LE3	7.0
113	CAE	LE3	AIS 227 LE3	6.9
114	CAE	LE3	AIT 228 LE3	6.7
115	CAE	LE3	AIU 229 LE3	6.9
116	CAE	LE3	AIX 232 LE3	5.8
117	CAE	LE3	AUA 469 LE3	6.4
118	CAE	LE3	AUB 470 LE3	7.0
119	CAE	LE3	AUC 471 LE3	6.3
120	CAE	LE3	AUD 472 LE3	5.9
121	CAE	LE3	AUE 473 LE3	6.0
122	CAE	LE3	AUF 474 LE3	6.0
123	CAE	LE3	AUG 475 LE3	6.0
124	CAE	LE3	AUH 476 LE3	6.0
125	CAE	LE3	AUI 477 LE3	6.1
126	CAE	LE3	AUJ 478 LE3	6.0
127	CAE	LE4	AJA 235 LE4	5.5
128	CAE	LE4	AJA 343 LE4	5.8
129	CAE	LE4	AJB 236 LE4	5.8
130	CAE	LE4	AJB 344 LE4	5.8
131	CAE	LE4	AJC 237 LE4	5.7
132	CAE	LE4	AJC 345 LE4	5.7
133	CAE	LE4	AJD 238 LE4	5.7
134	CAE	LE4	AJD 346 LE4	5.3
135	CAE	LE4	AJE 239 LE4	5.7
136	CAE	LE4	AJE 347 LE4	5.8
137	CAE	LE4	AJF 240 LE4	5.7
138	CAE	LE4	AJF 348 LE4	5.5
139	CAE	LE4	AJG 241 LE4	5.3
140	CAE	LE4	AJG 349 LE4	5.3
141	CAE	LE4	AJH 242 LE4	5.0
142	CAE	LE4	AJH 350 LE4	5.5
143	CAE	LE4	AJI 243 LE4	5.1
144	CAE	LE4	AJI 351 LE4	5.7
145	CAE	LE4	AJJ 244 LE4	5.4
146	CAE	LE4	AJK 245 LE4	5.6
147	CAE	LE4	AJK 352 LE4	5.6
148	CAE	LE4	AJL 246 LE4	5.9
149	CAE	LE4	AJM 247 LE4	6.4
150	CAE	LE4	AJN 248 LE4	6.4
151	CAE	LE4	AJO 249 LE4	6.7
152	CAE	LE4	AJP 250 LE4	5.3

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
153	CAE	LE4	AJQ 251 LE4	5.0
154	CAE	LE4	AJR 252 LE4	6.3
155	CAE	LE4	AJS 253 LE4	5.2
156	CAE	LE4	AJT 254 LE4	6.6
157	CAE	LE4	AJU 255 LE4	5.0
158	CAE	LE4	AJX 258 LE4	6.4
159	CAE	LE4	AVA 481 LE4	5.6
160	CAE	LE4	AVB 482 LE4	5.6
161	CAE	LE4	AVC 483 LE4	5.4
162	CAE	LE4	AVD 484 LE4	5.6
163	CAE	LE4	AVE 485 LE4	5.5
164	CAE	LE4	AVF 486 LE4	5.6
165	CAE	LE4	AVG 487 LE4	5.3
166	CAE	LE4	AVH 488 LE4	5.8
167	CAE	LE4	AVI 489 LE4	6.2
168	CAE	LE4	AVJ 490 LE4	6.0
169	CAE	LE5	AKA 261 LE5	6.2
170	CAE	LE5	AKA 353 LE5	6.0
171	CAE	LE5	AKB 262 LE5	6.5
172	CAE	LE5	AKB 354 LE5	6.3
173	CAE	LE5	AKC 263 LE5	6.2
174	CAE	LE5	AKC 355 LE5	5.7
175	CAE	LE5	AKD 264 LE5	6.4
176	CAE	LE5	AKD 356 LE5	6.0
177	CAE	LE5	AKE 265 LE5	5.5
178	CAE	LE5	AKE 357 LE5	6.0
179	CAE	LE5	AKF 266 LE5	5.9
180	CAE	LE5	AKF 358 LE5	5.5
181	CAE	LE5	AKG 267 LE5	5.6
182	CAE	LE5	AKG 359 LE5	5.8
183	CAE	LE5	AKH 268 LE5	5.4
184	CAE	LE5	AKH 360 LE5	6.4
185	CAE	LE5	AKI 269 LE5	5.5
186	CAE	LE5	AKI 361 LE5	6.3
187	CAE	LE5	AKJ 270 LE5	5.5
188	CAE	LE5	AKK 271 LE5	5.6
189	CAE	LE5	AKK 362 LE5	6.6
190	CAE	LE5	AKL 272 LE5	6.6
191	CAE	LE5	AKM 273 LE5	5.1
192	CAE	LE5	AKN 274 LE5	7.1
193	CAE	LE5	AKO 275 LE5	5.7
194	CAE	LE5	AKP 276 LE5	7.6
195	CAE	LE5	AKQ 277 LE5	5.8
196	CAE	LE5	AKR 278 LE5	5.4
197	CAE	LE5	AKS 279 LE5	5.7
198	CAE	LE5	AKT 280 LE5	5.8
199	CAE	LE5	AKU 281 LE5	5.6
200	CAE	LE5	AKX 284 LE5	6.0
201	CAE	LE5	AWA 493 LE5	6.1
202	CAE	LE5	AWB 494 LE5	5.4
203	CAE	LE5	AWC 495 LE5	6.0
204	CAE	LE5	AWD 496 LE5	6.0
205	CAE	LE5	AWE 497 LE5	5.9
206	CAE	LE5	AWF 498 LE5	6.0
207	CAE	LE5	AWG 499 LE5	5.9
208	CAE	LE5	AWH 500 LE5	6.0
209	CAE	LE5	AWI 501 LE5	5.9
210	CAE	LE5	AWJ 502 LE5	5.9
211	CAE	LE6	ALA 287 LE6	5.7
212	CAE	LE6	ALA 363 LE6	5.5
213	CAE	LE6	ALB 288 LE6	5.6
214	CAE	LE6	ALB 364 LE6	5.5
215	CAE	LE6	ALC 289 LE6	5.5
216	CAE	LE6	ALC 365 LE6	5.5
217	CAE	LE6	ALD 290 LE6	5.5
218	CAE	LE6	ALD 366 LE6	5.0
219	CAE	LE6	ALE 291 LE6	5.1
220	CAE	LE6	ALF 292 LE6	5.2
221	CAE	LE6	ALF 368 LE6	5.3
222	CAE	LE6	ALG 293 LE6	5.6
223	CAE	LE6	ALG 369 LE6	5.5
224	CAE	LE6	ALH 294 LE6	6.5
225	CAE	LE6	ALH 370 LE6	5.4
226	CAE	LE6	ALI 295 LE6	6.6
227	CAE	LE6	ALI 371 LE6	5.2
228	CAE	LE6	ALJ 296 LE6	4.9

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
229	CAE	LE6	ALK 297 LE6	6.4
230	CAE	LE6	ALK 372 LE6	5.4
231	CAE	LE6	ALL 298 LE6	7.3
232	CAE	LE6	ALM 299 LE6	6.6
233	CAE	LE6	ALN 300 LE6	6.4
234	CAE	LE6	ALO 301 LE6	5.2
235	CAE	LE6	ALP 302 LE6	5.5
236	CAE	LE6	ALQ 303 LE6	6.4
237	CAE	LE6	ALR 304 LE6	6.9
238	CAE	LE6	ALS 305 LE6	5.1
239	CAE	LE6	ALT 306 LE6	5.3
240	CAE	LE6	ALU 307 LE6	5.1
241	CAE	LE6	ALV 308 LE6	5.0
242	CAE	LE6	ALX 310 LE6	5.6
243	CAE	LE6	AXA 505 LE6	5.2
244	CAE	LE6	AXC 507 LE6	5.2
245	CAE	LE6	AXD 508 LE6	5.1
246	CAE	LE6	AXE 509 LE6	5.3
247	CAE	LE6	AXF 510 LE6	5.4
248	CAE	LE6	AXG 511 LE6	5.2
249	CAE	LE6	AXH 512 LE6	5.3
250	CAE	LE6	AXI 513 LE6	5.2
251	CAE	LE6	AXJ 514 LE6	5.3
252	CAE	LE6	AXL 516 LE6	5.3
253	CAE	LN1	AAA 001 LN1	5.1
254	CAE	LN1	AAB 002 LN1	5.1
255	CAE	LN1	AAD 004 LN1	4.8
256	CAE	LN1	AAE 005 LN1	5.5
257	CAE	LN1	AAF 006 LN1	5.0
258	CAE	LN1	AAG 007 LN1	6.9
259	CAE	LN1	AAH 008 LN1	6.3
260	CAE	LN1	AAI 009 LN1	6.5
261	CAE	LN1	AAJ 010 LN1	6.2
262	CAE	LN1	AAK 011 LN1	5.8
263	CAE	LN1	AAL 012 LN1	5.1
264	CAE	LN1	AAM 013 LN1	6.1
265	CAE	LN1	AAN 014 LN1	6.1
266	CAE	LN1	AAO 015 LN1	6.4
267	CAE	LN1	AAP 016 LN1	5.1
268	CAE	LN1	AAQ 017 LN1	6.4
269	CAE	LN1	AAR 018 LN1	5.9
270	CAE	LN1	AAS 019 LN1	6.1
271	CAE	LN1	AAT 020 LN1	6.4
272	CAE	LN1	AAU 021 LN1	6.1
273	CAE	LN1	AAV 022 LN1	5.1
274	CAE	LN1	ACC 003 LN1	5.1
275	CAE	LN1	AMA 373 LN1	6.2
276	CAE	LN1	AMB 374 LN1	6.5
277	CAE	LN1	AMC 375 LN1	6.5
278	CAE	LN1	AMD 376 LN1	6.6
279	CAE	LN1	AME 377 LN1	6.1
280	CAE	LN1	AMF 378 LN1	5.5
281	CAE	LN1	AMG 379 LN1	5.6
282	CAE	LN1	AMH 380 LN1	5.9
283	CAE	LN1	AMI 381 LN1	5.9
284	CAE	LN1	AMJ 382 LN1	5.8
285	CAE	LN2	ABA 027 LN2	5.7
286	CAE	LN2	ABB 028 LN2	5.5
287	CAE	LN2	ABC 029 LN2	5.6
288	CAE	LN2	ABD 030 LN2	5.6
289	CAE	LN2	ABE 031 LN2	6.5
290	CAE	LN2	ABF 032 LN2	5.9
291	CAE	LN2	ABG 033 LN2	6.1
292	CAE	LN2	ABH 034 LN2	5.4
293	CAE	LN2	ABI 035 LN2	5.7
294	CAE	LN2	ABJ 036 LN2	5.7
295	CAE	LN2	ABK 037 LN2	6.6
296	CAE	LN2	ABL 038 LN2	6.2
297	CAE	LN2	ABM 039 LN2	5.5
298	CAE	LN2	ABN 040 LN2	5.4
299	CAE	LN2	ABO 041 LN2	6.0
300	CAE	LN2	ABP 042 LN2	5.9
301	CAE	LN2	ABQ 043 LN2	5.7
302	CAE	LN2	ABR 044 LN2	5.6
303	CAE	LN2	ABS 045 LN2	5.6
304	CAE	LN2	ABT 046 LN2	5.7

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
305	CAE	LN2	ABU 047 LN2	5.8
306	CAE	LN2	ABV 048 LN2	5.7
307	CAE	LN2	ANA 385 LN2	5.7
308	CAE	LN2	ANC 387 LN2	5.3
309	CAE	LN2	AND 388 LN2	5.4
310	CAE	LN2	ANE 389 LN2	5.3
311	CAE	LN2	ANF 390 LN2	5.3
312	CAE	LN2	ANG 391 LN2	5.3
313	CAE	LN2	ANH 392 LN2	5.0
314	CAE	LN2	ANI 393 LN2	5.0
315	CAE	LN2	ANJ 394 LN2	5.0
316	CAE	LN2	ANL 396 LN2	5.0
317	CAE	LN3	ACA 053 LN3	10.1
318	CAE	LN3	ACB 054 LN3	10.2
319	CAE	LN3	ACC 055 LN3	10.3
320	CAE	LN3	ACD 056 LN3	9.9
321	CAE	LN3	ACE 057 LN3	10.2
322	CAE	LN3	ACF 058 LN3	11.3
323	CAE	LN3	ACG 059 LN3	10.4
324	CAE	LN3	ACH 060 LN3	10.6
325	CAE	LN3	ACI 061 LN3	11.4
326	CAE	LN3	ACJ 062 LN3	11.3
327	CAE	LN3	ACK 063 LN3	14.2
328	CAE	LN3	ACL 064 LN3	9.7
329	CAE	LN3	ACM 065 LN3	11.0
330	CAE	LN3	ACN 066 LN3	10.9
331	CAE	LN3	ACO 067 LN3	11.3
332	CAE	LN3	ACP 068 LN3	12.0
333	CAE	LN3	ACQ 069 LN3	10.9
334	CAE	LN3	ACR 070 LN3	10.6
335	CAE	LN3	ACS 071 LN3	11.0
336	CAE	LN3	ACT 072 LN3	10.8
337	CAE	LN3	ACU 073 LN3	11.4
338	CAE	LN3	ACV 074 LN3	11.4
339	CAE	LN3	AOA 397 LN3	11.6
340	CAE	LN3	AOB 398 LN3	11.3
341	CAE	LN3	AOC 399 LN3	10.9
342	CAE	LN3	AOD 400 LN3	11.7
343	CAE	LN3	AOE 401 LN3	11.8
344	CAE	LN3	AOF 402 LN3	11.3
345	CAE	LN3	AOG 403 LN3	10.8
346	CAE	LN3	AOH 404 LN3	10.8
347	CAE	LN3	AOI 405 LN3	11.7
348	CAE	LN3	AOJ 406 LN3	11.0
349	CAE	LN4	ACF 084 LN4	5.5
350	CAE	LN4	ADA 079 LN4	5.0
351	CAE	LN4	ADB 080 LN4	5.0
352	CAE	LN4	ADC 081 LN4	5.0
353	CAE	LN4	ADD 082 LN4	4.9
354	CAE	LN4	ADE 083 LN4	5.3
355	CAE	LN4	ADG 085 LN4	5.1
356	CAE	LN4	ADH 086 LN4	5.9
357	CAE	LN4	ADI 087 LN4	5.8
358	CAE	LN4	ADJ 088 LN4	5.8
359	CAE	LN4	ADL 090 LN4	6.4
360	CAE	LN4	ADM 091 LN4	5.6
361	CAE	LN4	ADN 092 LN4	4.9
362	CAE	LN4	ADO 093 LN4	5.8
363	CAE	LN4	ADP 094 LN4	6.1
364	CAE	LN4	ADQ 095 LN4	5.6
365	CAE	LN4	ADR 096 LN4	5.4
366	CAE	LN4	ADS 097 LN4	5.9
367	CAE	LN4	ADT 098 LN4	5.7
368	CAE	LN4	ADU 099 LN4	6.0
369	CAE	LN4	ADV 100 LN4	5.8
370	CAE	LN4	ADX 089 LN4	5.8
371	CAE	LN4	APA 409 LN4	5.5
372	CAE	LN4	APB 410 LN4	5.0
373	CAE	LN4	APC 411 LN4	5.5
374	CAE	LN4	APD 412 LN4	5.8
375	CAE	LN4	APE 413 LN4	5.4
376	CAE	LN4	APF 414 LN4	5.8
377	CAE	LN4	APG 415 LN4	5.6
378	CAE	LN4	APH 416 LN4	5.5
379	CAE	LN4	API 417 LN4	6.4
380	CAE	LN4	APJ 418 LN4	5.4

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
381	CAE	LN5	AEA 105 LN5	11.1
382	CAE	LN5	AEB 106 LN5	10.8
383	CAE	LN5	AEC 107 LN5	10.9
384	CAE	LN5	AED 108 LN5	10.3
385	CAE	LN5	AEE 109 LN5	10.8
386	CAE	LN5	AEF 110 LN5	12.3
387	CAE	LN5	AEG 111 LN5	11.6
388	CAE	LN5	AEH 112 LN5	11.6
389	CAE	LN5	AEI 113 LN5	10.6
390	CAE	LN5	AEJ 114 LN5	12.0
391	CAE	LN5	AEK 115 LN5	14.7
392	CAE	LN5	AEL 116 LN5	13.6
393	CAE	LN5	AEM 117 LN5	11.7
394	CAE	LN5	AEN 118 LN5	11.5
395	CAE	LN5	AEO 119 LN5	12.1
396	CAE	LN5	AEP 120 LN5	13.1
397	CAE	LN5	AEQ 121 LN5	11.5
398	CAE	LN5	AER 122 LN5	11.8
399	CAE	LN5	AES 123 LN5	11.5
400	CAE	LN5	AET 124 LN5	10.2
401	CAE	LN5	AEU 125 LN5	9.9
402	CAE	LN5	AEV 126 LN5	11.9
403	CAE	LN5	AQB 421 LN5	12.2
404	CAE	LN5	AQB 422 LN5	12.1
405	CAE	LN5	AQC 423 LN5	10.9
406	CAE	LN5	AQD 424 LN5	10.9
407	CAE	LN5	AQE 425 LN5	11.0
408	CAE	LN5	AQF 426 LN5	11.3
409	CAE	LN5	AQG 427 LN5	11.4
410	CAE	LN5	AQH 428 LN5	11.1
411	CAE	LN5	AQI 429 LN5	11.4
412	CAE	LN5	AQJ 430 LN5	11.6
413	CAE	LN6	AFA 131 LN6	11.5
414	CAE	LN6	AFB 132 LN6	11.7
415	CAE	LN6	AFC 133 LN6	12.2
416	CAE	LN6	AFD 134 LN6	.
417	CAE	LN6	AFE 135 LN6	11.3
418	CAE	LN6	AFF 136 LN6	10.4
419	CAE	LN6	AFG 137 LN6	10.4
420	CAE	LN6	AFH 138 LN6	10.6
421	CAE	LN6	AFI 139 LN6	11.1
422	CAE	LN6	AFJ 140 LN6	10.5
423	CAE	LN6	AFK 141 LN6	11.9
424	CAE	LN6	AFL 142 LN6	10.2
425	CAE	LN6	AFM 143 LN6	10.3
426	CAE	LN6	AFN 144 LN6	10.6
427	CAE	LN6	AFO 145 LN6	10.5
428	CAE	LN6	AFP 146 LN6	11.3
429	CAE	LN6	AFQ 147 LN6	12.6
430	CAE	LN6	AFR 148 LN6	10.1
431	CAE	LN6	AFS 149 LN6	10.2
432	CAE	LN6	AFT 150 LN6	10.7
433	CAE	LN6	AFV 152 LN6	13.2
434	CAE	LN6	AFX 154 LN6	11.3
435	CAE	LN6	ARA 433 LN6	12.2
436	CAE	LN6	ARB 434 LN6	13.5
437	CAE	LN6	ARC 435 LN6	12.0
438	CAE	LN6	ARD 436 LN6	11.7
439	CAE	LN6	ARE 437 LN6	11.9
440	CAE	LN6	ARF 438 LN6	12.6
441	CAE	LN6	ARG 439 LN6	13.0
442	CAE	LN6	ARH 440 LN6	13.6
443	CAE	LN6	ARI 441 LN6	11.6
444	CAE	LN6	ARJ 442 LN6	12.8
445	CAE	RE1	BBA 553 RE1	331.8
446	CAE	RE1	BBB 554 RE1	250.9
447	CAE	RE1	BBC 555 RE1	337.6
448	CAE	RE1	BBD 556 RE1	333.8
449	CAE	RE1	BBE 557 RE1	286.0
450	CAE	RE1	BBF 558 RE1	303.4
451	CAE	RE1	BBG 559 RE1	300.6
452	CAE	RE1	BBH 560 RE1	314.2
453	CAE	RE1	BBI 561 RE1	343.5
454	CAE	RE1	BBJ 562 RE1	340.6
455	CAE	RE1	BHA 658 RE1	321.9
456	CAE	RE1	BHB 659 RE1	261.6

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
457	CAE	RE1	BHC 660 RE1	284.3
458	CAE	RE1	BHD 661 RE1	217.6
459	CAE	RE1	BHE 662 RE1	206.2
460	CAE	RE1	BHF 663 RE1	188.8
461	CAE	RE1	BHG 664 RE1	200.3
462	CAE	RE1	BHH 665 RE1	301.6
463	CAE	RE1	BHI 666 RE1	285.2
464	CAE	RE1	BHJ 667 RE1	268.1
465	CAE	RE1	BHK 668 RE1	164.9
466	CAE	RE1	BHL 669 RE1	195.9
467	CAE	RE1	BHM 670 RE1	317.1
468	CAE	RE1	BHN 671 RE1	270.3
469	CAE	RE1	BHO 672 RE1	298.7
470	CAE	RE1	BHP 673 RE1	251.4
471	CAE	RE1	BHQ 674 RE1	238.3
472	CAE	RE1	BHR 675 RE1	267.3
473	CAE	RE1	BHS 676 RE1	256.2
474	CAE	RE1	BKA 728 RE1	167.9
475	CAE	RE1	BKB 729 RE1	162.1
476	CAE	RE1	BKC 730 RE1	177.9
477	CAE	RE1	BKD 731 RE1	176.1
478	CAE	RE1	BKE 732 RE1	187.4
479	CAE	RE1	BKF 733 RE1	164.3
480	CAE	RE1	BKH 735 RE1	260.8
481	CAE	RE1	BKI 736 RE1	251.8
482	CAE	RE1	BKJ 737 RE1	244.3
483	CAE	RE2	BCA 565 RE2	20.4
484	CAE	RE2	BCB 566 RE2	18.7
485	CAE	RE2	BCC 567 RE2	18.6
486	CAE	RE2	BCD 568 RE2	20.8
487	CAE	RE2	BCE 569 RE2	21.8
488	CAE	RE2	BCF 570 RE2	18.8
489	CAE	RE2	BCG 571 RE2	21.2
490	CAE	RE2	BCH 572 RE2	16.1
491	CAE	RE2	BCI 573 RE2	19.5
492	CAE	RE2	BCJ 574 RE2	20.9
493	CAE	RE2	BIA 681 RE2	23.0
494	CAE	RE2	BIB 682 RE2	19.6
495	CAE	RE2	BIC 683 RE2	21.3
496	CAE	RE2	BID 684 RE2	28.5
497	CAE	RE2	BIE 685 RE2	24.3
498	CAE	RE2	BIF 686 RE2	24.6
499	CAE	RE2	BIG 687 RE2	21.6
500	CAE	RE2	BIH 688 RE2	26.8
501	CAE	RE2	BII 689 RE2	21.1
502	CAE	RE2	BIJ 690 RE2	24.9
503	CAE	RE2	BIK 691 RE2	29.3
504	CAE	RE2	BIL 692 RE2	23.2
505	CAE	RE2	BIM 693 RE2	24.0
506	CAE	RE2	BIN 694 RE2	20.7
507	CAE	RE2	BIO 695 RE2	29.3
508	CAE	RE2	BIP 696 RE2	19.4
509	CAE	RE2	BIQ 697 RE2	21.1
510	CAE	RE2	BIR 698 RE2	20.9
511	CAE	RE2	BIS 699 RE2	22.5
512	CAE	RE2	BLA 738 RE2	23.8
513	CAE	RE2	BLB 739 RE2	22.4
514	CAE	RE2	BLC 740 RE2	22.4
515	CAE	RE2	BLD 741 RE2	22.5
516	CAE	RE2	BLE 742 RE2	18.2
517	CAE	RE2	BLF 743 RE2	18.8
518	CAE	RE2	BLH 745 RE2	21.2
519	CAE	RE2	BLI 746 RE2	19.4
520	CAE	RE2	BLJ 747 RE2	21.9
521	CAE	RE3	BDA 577 RE3	20.4
522	CAE	RE3	BDB 578 RE3	22.7
523	CAE	RE3	BDC 579 RE3	20.0
524	CAE	RE3	BDD 580 RE3	19.6
525	CAE	RE3	BDE 581 RE3	19.3
526	CAE	RE3	BDF 582 RE3	23.6
527	CAE	RE3	BDG 583 RE3	19.1
528	CAE	RE3	BDH 584 RE3	23.5
529	CAE	RE3	BDI 585 RE3	23.0
530	CAE	RE3	BDJ 586 RE3	23.4
531	CAE	RE3	BJA 704 RE3	23.3
532	CAE	RE3	BJB 705 RE3	22.4

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
533	CAE	RE3	BJC 706 RE3	22.7
534	CAE	RE3	BJD 707 RE3	21.7
535	CAE	RE3	BJE 708 RE3	21.8
536	CAE	RE3	BJF 709 RE3	22.3
537	CAE	RE3	BJG 710 RE3	17.9
538	CAE	RE3	BJH 711 RE3	25.2
539	CAE	RE3	BJI 712 RE3	19.0
540	CAE	RE3	BJJ 713 RE3	21.7
541	CAE	RE3	BJK 714 RE3	30.2
542	CAE	RE3	BJL 715 RE3	24.6
543	CAE	RE3	BJM 716 RE3	22.0
544	CAE	RE3	BJN 717 RE3	20.6
545	CAE	RE3	BJO 718 RE3	25.7
546	CAE	RE3	BJQ 720 RE3	18.0
547	CAE	RE3	BJR 721 RE3	.
548	CAE	RE3	BJS 722 RE3	20.3
549	CAE	RE3	BJT 723 RE3	18.3
550	CAE	RE3	BMA 748 RE3	21.7
551	CAE	RE3	BMB 749 RE3	21.5
552	CAE	RE3	BMC 750 RE3	22.6
553	CAE	RE3	BMD 751 RE3	18.4
554	CAE	RE3	BME 752 RE3	15.4
555	CAE	RE3	BMF 753 RE3	18.5
556	CAE	RE3	BMH 755 RE3	23.3
557	CAE	RE3	BMI 756 RE3	19.3
558	CAE	RE3	BMJ 757 RE3	20.9
559	CAE	RN1	AYA 517 RN1	16.4
560	CAE	RN1	AYB 518 RN1	16.5
561	CAE	RN1	AYC 519 RN1	18.2
562	CAE	RN1	AYD 520 RN1	19.3
563	CAE	RN1	AYE 521 RN1	19.8
564	CAE	RN1	AYF 522 RN1	16.7
565	CAE	RN1	AYG 523 RN1	18.4
566	CAE	RN1	AYH 524 RN1	18.3
567	CAE	RN1	AYI 525 RN1	19.8
568	CAE	RN1	AYJ 526 RN1	19.8
569	CAE	RN1	BEA 589 RN1	20.4
570	CAE	RN1	BEB 590 RN1	20.1
571	CAE	RN1	BEC 591 RN1	20.6
572	CAE	RN1	BED 592 RN1	20.6
573	CAE	RN1	BEE 593 RN1	20.1
574	CAE	RN1	BEF 594 RN1	18.0
575	CAE	RN1	BEG 595 RN1	20.7
576	CAE	RN1	BEH 596 RN1	18.8
577	CAE	RN1	BEI 597 RN1	18.8
578	CAE	RN1	BEJ 598 RN1	18.4
579	CAE	RN1	BEK 599 RN1	19.8
580	CAE	RN1	BEL 600 RN1	18.7
581	CAE	RN1	BEM 601 RN1	17.4
582	CAE	RN1	BEN 602 RN1	17.1
583	CAE	RN1	BEO 603 RN1	18.9
584	CAE	RN1	BEP 604 RN1	16.9
585	CAE	RN1	BEQ 605 RN1	17.4
586	CAE	RN1	BER 606 RN1	16.0
587	CAE	RN1	BES 607 RN1	16.9
588	CAE	RN2	AZA 529 RN2	18.2
589	CAE	RN2	AZB 530 RN2	18.2
590	CAE	RN2	AZC 531 RN2	16.8
591	CAE	RN2	AZD 532 RN2	21.0
592	CAE	RN2	AZE 533 RN2	17.0
593	CAE	RN2	AZF 534 RN2	17.6
594	CAE	RN2	AZG 535 RN2	18.4
595	CAE	RN2	AZH 536 RN2	16.5
596	CAE	RN2	AZI 537 RN2	15.8
597	CAE	RN2	AZJ 538 RN2	16.8
598	CAE	RN2	BFA 612 RN2	21.1
599	CAE	RN2	BFB 613 RN2	20.6
600	CAE	RN2	BFC 614 RN2	21.0
601	CAE	RN2	BFD 615 RN2	23.7
602	CAE	RN2	BFE 616 RN2	19.9
603	CAE	RN2	BFF 617 RN2	20.5
604	CAE	RN2	BFG 618 RN2	17.2
605	CAE	RN2	BFH 619 RN2	17.9
606	CAE	RN2	BFI 620 RN2	19.2
607	CAE	RN2	BFJ 621 RN2	20.2
608	CAE	RN2	BFK 622 RN2	25.0

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
609	CAE	RN2	BFL 623 RN2	24.5
610	CAE	RN2	BFM 624 RN2	16.7
611	CAE	RN2	BFN 625 RN2	17.7
612	CAE	RN2	BFO 626 RN2	18.1
613	CAE	RN2	BFP 627 RN2	16.7
614	CAE	RN2	BFQ 628 RN2	19.8
615	CAE	RN2	BFR 629 RN2	18.2
616	CAE	RN2	BFS 630 RN2	16.5
617	CAE	RN3	BAA 541 RN3	12.1
618	CAE	RN3	BAB 542 RN3	18.4
619	CAE	RN3	BAC 543 RN3	18.0
620	CAE	RN3	BAD 544 RN3	13.1
621	CAE	RN3	BAE 545 RN3	12.3
622	CAE	RN3	BAF 546 RN3	16.2
623	CAE	RN3	BAG 547 RN3	13.6
624	CAE	RN3	BAH 548 RN3	13.6
625	CAE	RN3	BAI 549 RN3	13.6
626	CAE	RN3	BAJ 550 RN3	13.0
627	CAE	RN3	BGA 635 RN3	14.9
628	CAE	RN3	BGB 636 RN3	15.2
629	CAE	RN3	BGC 637 RN3	15.5
630	CAE	RN3	BGD 638 RN3	12.5
631	CAE	RN3	BGE 639 RN3	11.6
632	CAE	RN3	BGF 640 RN3	13.5
633	CAE	RN3	BGG 641 RN3	12.1
634	CAE	RN3	BGH 642 RN3	14.3
635	CAE	RN3	BGI 643 RN3	15.4
636	CAE	RN3	BGJ 644 RN3	15.5
637	CAE	RN3	BGK 645 RN3	13.0
638	CAE	RN3	BGL 646 RN3	15.2
639	CAE	RN3	BGM 647 RN3	13.2
640	CAE	RN3	BGN 648 RN3	12.3
641	CAE	RN3	BGO 649 RN3	13.6
642	CAE	RN3	BGP 650 RN3	11.9
643	CAE	RN3	BGQ 651 RN3	13.6
644	CAE	RN3	BGR 652 RN3	15.1
645	CAE	RN3	BGS 653 RN3	13.6
646	PSI	LE1	FF-LE1-1	7.4
647	PSI	LE1	FF-LE1-10	9.1
648	PSI	LE1	FF-LE1-2	7.4
649	PSI	LE1	FF-LE1-3	10.1
650	PSI	LE1	FF-LE1-4	7.4
651	PSI	LE1	FF-LE1-5	7.0
652	PSI	LE1	FF-LE1-6	7.0
653	PSI	LE1	FF-LE1-7	10.0
654	PSI	LE1	FF-LE1-8	9.4
655	PSI	LE1	FF-LE1-9	9.1
656	PSI	LE1	LE1-1	4.4
657	PSI	LE1	LE1-10	7.8
658	PSI	LE1	LE1-11	7.0
659	PSI	LE1	LE1-12	6.8
660	PSI	LE1	LE1-13	7.4
661	PSI	LE1	LE1-14	7.2
662	PSI	LE1	LE1-15	7.0
663	PSI	LE1	LE1-16	6.8
664	PSI	LE1	LE1-17	7.3
665	PSI	LE1	LE1-18	6.7
666	PSI	LE1	LE1-19	6.4
667	PSI	LE1	LE1-2	7.9
668	PSI	LE1	LE1-20	7.1
669	PSI	LE1	LE1-21	6.7
670	PSI	LE1	LE1-22	6.9
671	PSI	LE1	LE1-23	6.5
672	PSI	LE1	LE1-24	7.1
673	PSI	LE1	LE1-25	6.2
674	PSI	LE1	LE1-26	4.7
675	PSI	LE1	LE1-27	6.8
676	PSI	LE1	LE1-28	6.7
677	PSI	LE1	LE1-29	7.2
678	PSI	LE1	LE1-3	4.9
679	PSI	LE1	LE1-30	7.4
680	PSI	LE1	LE1-31	7.4
681	PSI	LE1	LE1-4	4.9
682	PSI	LE1	LE1-5	7.1
683	PSI	LE1	LE1-6	4.4
684	PSI	LE1	LE1-7	6.9

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
685	PSI	LE1	LE1-8	7.2
686	PSI	LE1	LE1-9	7.2
687	PSI	LE2	FF-LE2-1	6.0
688	PSI	LE2	FF-LE2-10	6.0
689	PSI	LE2	FF-LE2-2	6.1
690	PSI	LE2	FF-LE2-3	6.2
691	PSI	LE2	FF-LE2-4	5.9
692	PSI	LE2	FF-LE2-5	6.1
693	PSI	LE2	FF-LE2-6	6.3
694	PSI	LE2	FF-LE2-7	6.0
695	PSI	LE2	FF-LE2-8	5.9
696	PSI	LE2	FF-LE2-9	6.0
697	PSI	LE2	LE2-1	5.2
698	PSI	LE2	LE2-10	6.1
699	PSI	LE2	LE2-11	5.5
700	PSI	LE2	LE2-12	6.1
701	PSI	LE2	LE2-13	5.6
702	PSI	LE2	LE2-14	5.6
703	PSI	LE2	LE2-15	5.6
704	PSI	LE2	LE2-16	5.6
705	PSI	LE2	LE2-17	5.7
706	PSI	LE2	LE2-18	5.3
707	PSI	LE2	LE2-19	5.7
708	PSI	LE2	LE2-2	4.9
709	PSI	LE2	LE2-20	5.7
710	PSI	LE2	LE2-21	6.2
711	PSI	LE2	LE2-22	6.2
712	PSI	LE2	LE2-23	5.8
713	PSI	LE2	LE2-24	5.9
714	PSI	LE2	LE2-25	5.7
715	PSI	LE2	LE2-26	5.3
716	PSI	LE2	LE2-27	6.4
717	PSI	LE2	LE2-28	6.7
718	PSI	LE2	LE2-29	6.9
719	PSI	LE2	LE2-3	5.6
720	PSI	LE2	LE2-30	5.8
721	PSI	LE2	LE2-31	5.8
722	PSI	LE2	LE2-4	5.6
723	PSI	LE2	LE2-5	5.1
724	PSI	LE2	LE2-6	5.4
725	PSI	LE2	LE2-7	5.7
726	PSI	LE2	LE2-8	5.6
727	PSI	LE2	LE2-9	5.8
728	PSI	LE3	FF-LE3-1	7.5
729	PSI	LE3	FF-LE3-10	.
730	PSI	LE3	FF-LE3-2	7.5
731	PSI	LE3	FF-LE3-3	7.5
732	PSI	LE3	FF-LE3-4	7.5
733	PSI	LE3	FF-LE3-5	.
734	PSI	LE3	FF-LE3-6	.
735	PSI	LE3	FF-LE3-7	.
736	PSI	LE3	FF-LE3-8	.
737	PSI	LE3	FF-LE3-9	.
738	PSI	LE3	LE3-1	6.9
739	PSI	LE3	LE3-10	6.5
740	PSI	LE3	LE3-11	5.3
741	PSI	LE3	LE3-12	5.4
742	PSI	LE3	LE3-13	5.4
743	PSI	LE3	LE3-14	5.2
744	PSI	LE3	LE3-15	5.3
745	PSI	LE3	LE3-16	5.8
746	PSI	LE3	LE3-17	5.0
747	PSI	LE3	LE3-18	6.6
748	PSI	LE3	LE3-19	6.7
749	PSI	LE3	LE3-2	6.8
750	PSI	LE3	LE3-20	6.8
751	PSI	LE3	LE3-21	6.7
752	PSI	LE3	LE3-22	6.7
753	PSI	LE3	LE3-23	6.9
754	PSI	LE3	LE3-24	6.9
755	PSI	LE3	LE3-25	4.9
756	PSI	LE3	LE3-26	4.9
757	PSI	LE3	LE3-27	4.9
758	PSI	LE3	LE3-28	5.2
759	PSI	LE3	LE3-29	4.8
760	PSI	LE3	LE3-3	6.8

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
761	PSI	LE3	LE3-30	4.8
762	PSI	LE3	LE3-31	4.8
763	PSI	LE3	LE3-4	6.3
764	PSI	LE3	LE3-5	6.5
765	PSI	LE3	LE3-6	6.1
766	PSI	LE3	LE3-7	6.6
767	PSI	LE3	LE3-8	6.7
768	PSI	LE3	LE3-9	7.1
769	PSI	LE4	FF-LE4-1	8.8
770	PSI	LE4	FF-LE4-10	8.6
771	PSI	LE4	FF-LE4-2	8.8
772	PSI	LE4	FF-LE4-3	8.6
773	PSI	LE4	FF-LE4-4	8.6
774	PSI	LE4	FF-LE4-5	8.6
775	PSI	LE4	FF-LE4-6	8.6
776	PSI	LE4	FF-LE4-7	8.6
777	PSI	LE4	FF-LE4-8	8.6
778	PSI	LE4	FF-LE4-9	8.6
779	PSI	LE4	LE4-1	5.1
780	PSI	LE4	LE4-10	5.5
781	PSI	LE4	LE4-11	6.1
782	PSI	LE4	LE4-12	5.9
783	PSI	LE4	LE4-13	6.1
784	PSI	LE4	LE4-14	6.1
785	PSI	LE4	LE4-15	6.4
786	PSI	LE4	LE4-16	5.9
787	PSI	LE4	LE4-17	6.2
788	PSI	LE4	LE4-18	7.4
789	PSI	LE4	LE4-19	7.2
790	PSI	LE4	LE4-2	4.9
791	PSI	LE4	LE4-20	7.3
792	PSI	LE4	LE4-21	7.1
793	PSI	LE4	LE4-22	7.2
794	PSI	LE4	LE4-23	7.1
795	PSI	LE4	LE4-24	7.3
796	PSI	LE4	LE4-25	5.0
797	PSI	LE4	LE4-26	5.0
798	PSI	LE4	LE4-27	6.3
799	PSI	LE4	LE4-28	6.6
800	PSI	LE4	LE4-29	7.0
801	PSI	LE4	LE4-3	5.0
802	PSI	LE4	LE4-30	6.9
803	PSI	LE4	LE4-31	6.7
804	PSI	LE4	LE4-4	6.9
805	PSI	LE4	LE4-5	7.3
806	PSI	LE4	LE4-6	6.8
807	PSI	LE4	LE4-7	5.9
808	PSI	LE4	LE4-8	5.7
809	PSI	LE4	LE4-9	6.0
810	PSI	LE5	FF-LE5-1	5.6
811	PSI	LE5	FF-LE5-10	.
812	PSI	LE5	FF-LE5-2	5.6
813	PSI	LE5	FF-LE5-3	5.0
814	PSI	LE5	FF-LE5-4	5.3
815	PSI	LE5	FF-LE5-5	5.3
816	PSI	LE5	FF-LE5-6	.
817	PSI	LE5	FF-LE5-7	.
818	PSI	LE5	FF-LE5-8	.
819	PSI	LE5	FF-LE5-9	.
820	PSI	LE5	LE5-1	6.2
821	PSI	LE5	LE5-10	6.9
822	PSI	LE5	LE5-11	7.2
823	PSI	LE5	LE5-12	6.5
824	PSI	LE5	LE5-13	5.5
825	PSI	LE5	LE5-14	5.4
826	PSI	LE5	LE5-15	4.9
827	PSI	LE5	LE5-16	5.2
828	PSI	LE5	LE5-17	5.7
829	PSI	LE5	LE5-18	6.7
830	PSI	LE5	LE5-19	6.6
831	PSI	LE5	LE5-2	6.0
832	PSI	LE5	LE5-20	6.5
833	PSI	LE5	LE5-21	6.4
834	PSI	LE5	LE5-22	6.7
835	PSI	LE5	LE5-23	6.4
836	PSI	LE5	LE5-24	6.8

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
837	PSI	LE5	LE5-25	5.2
838	PSI	LE5	LE5-26	4.8
839	PSI	LE5	LE5-27	5.3
840	PSI	LE5	LE5-28	5.2
841	PSI	LE5	LE5-29	5.0
842	PSI	LE5	LE5-3	6.2
843	PSI	LE5	LE5-30	4.9
844	PSI	LE5	LE5-31	5.1
845	PSI	LE5	LE5-4	6.6
846	PSI	LE5	LE5-5	6.4
847	PSI	LE5	LE5-6	6.5
848	PSI	LE5	LE5-7	7.0
849	PSI	LE5	LE5-8	7.1
850	PSI	LE5	LE5-9	6.9
851	PSI	LE6	FF-LE6-1	4.7
852	PSI	LE6	FF-LE6-10	4.5
853	PSI	LE6	FF-LE6-2	4.6
854	PSI	LE6	FF-LE6-3	5.0
855	PSI	LE6	FF-LE6-4	.
856	PSI	LE6	FF-LE6-5	5.0
857	PSI	LE6	FF-LE6-6	5.6
858	PSI	LE6	FF-LE6-7	5.0
859	PSI	LE6	FF-LE6-8	4.0
860	PSI	LE6	FF-LE6-9	5.0
861	PSI	LE6	LE6-1	5.3
862	PSI	LE6	LE6-10	4.8
863	PSI	LE6	LE6-11	4.8
864	PSI	LE6	LE6-12	4.8
865	PSI	LE6	LE6-13	6.6
866	PSI	LE6	LE6-14	5.0
867	PSI	LE6	LE6-15	4.7
868	PSI	LE6	LE6-16	4.7
869	PSI	LE6	LE6-17	6.9
870	PSI	LE6	LE6-18	6.4
871	PSI	LE6	LE6-19	6.6
872	PSI	LE6	LE6-2	5.1
873	PSI	LE6	LE6-20	6.4
874	PSI	LE6	LE6-21	5.9
875	PSI	LE6	LE6-22	6.7
876	PSI	LE6	LE6-23	6.2
877	PSI	LE6	LE6-24	6.5
878	PSI	LE6	LE6-25	5.3
879	PSI	LE6	LE6-26	5.3
880	PSI	LE6	LE6-27	5.2
881	PSI	LE6	LE6-28	5.5
882	PSI	LE6	LE6-29	5.3
883	PSI	LE6	LE6-3	5.1
884	PSI	LE6	LE6-30	5.0
885	PSI	LE6	LE6-31	4.8
886	PSI	LE6	LE6-4	5.3
887	PSI	LE6	LE6-5	5.0
888	PSI	LE6	LE6-6	5.2
889	PSI	LE6	LE6-7	4.5
890	PSI	LE6	LE6-8	4.7
891	PSI	LE6	LE6-9	6.7
892	PSI	LN1	FF-LN1-1	6.8
893	PSI	LN1	FF-LN1-10	7.0
894	PSI	LN1	FF-LN1-2	7.0
895	PSI	LN1	FF-LN1-3	7.0
896	PSI	LN1	FF-LN1-4	7.0
897	PSI	LN1	FF-LN1-5	7.0
898	PSI	LN1	FF-LN1-6	7.0
899	PSI	LN1	FF-LN1-7	6.9
900	PSI	LN1	FF-LN1-8	7.0
901	PSI	LN1	FF-LN1-9	7.0
902	PSI	LN1	LN1-1	5.0
903	PSI	LN1	LN1-10	6.8
904	PSI	LN1	LN1-11	6.6
905	PSI	LN1	LN1-12	6.9
906	PSI	LN1	LN1-13	6.3
907	PSI	LN1	LN1-14	6.4
908	PSI	LN1	LN1-15	6.5
909	PSI	LN1	LN1-16	6.9
910	PSI	LN1	LN1-17	6.0
911	PSI	LN1	LN1-18	6.0
912	PSI	LN1	LN1-19	5.7

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
913	PSI	LN1	LN1-2	6.4
914	PSI	LN1	LN1-20	6.1
915	PSI	LN1	LN1-21	5.9
916	PSI	LN1	LN1-3	6.2
917	PSI	LN1	LN1-4	6.0
918	PSI	LN1	LN1-5	6.0
919	PSI	LN1	LN1-6	6.6
920	PSI	LN1	LN1-7	6.8
921	PSI	LN1	LN1-8	6.4
922	PSI	LN1	LN1-9	5.8
923	PSI	LN2	FF-LN2-1	.
924	PSI	LN2	FF-LN2-10	6.5
925	PSI	LN2	FF-LN2-2	6.7
926	PSI	LN2	FF-LN2-3	6.8
927	PSI	LN2	FF-LN2-4	7.0
928	PSI	LN2	FF-LN2-5	7.0
929	PSI	LN2	FF-LN2-6	6.8
930	PSI	LN2	FF-LN2-7	7.0
931	PSI	LN2	FF-LN2-8	7.0
932	PSI	LN2	FF-LN2-9	6.6
933	PSI	LN2	LN2-1	5.9
934	PSI	LN2	LN2-10	6.9
935	PSI	LN2	LN2-11	6.6
936	PSI	LN2	LN2-12	6.3
937	PSI	LN2	LN2-13	6.6
938	PSI	LN2	LN2-14	6.4
939	PSI	LN2	LN2-15	5.6
940	PSI	LN2	LN2-16	5.3
941	PSI	LN2	LN2-17	6.9
942	PSI	LN2	LN2-18	7.2
943	PSI	LN2	LN2-19	7.1
944	PSI	LN2	LN2-2	6.0
945	PSI	LN2	LN2-20	7.2
946	PSI	LN2	LN2-3	6.2
947	PSI	LN2	LN2-4	6.8
948	PSI	LN2	LN2-5	6.4
949	PSI	LN2	LN2-6	6.1
950	PSI	LN2	LN2-7	6.6
951	PSI	LN2	LN2-8	7.0
952	PSI	LN2	LN2-9	7.0
953	PSI	LN3	FF-LN3-1	14.0
954	PSI	LN3	FF-LN3-10	13.4
955	PSI	LN3	FF-LN3-2	14.1
956	PSI	LN3	FF-LN3-3	13.3
957	PSI	LN3	FF-LN3-4	12.4
958	PSI	LN3	FF-LN3-5	12.3
959	PSI	LN3	FF-LN3-6	12.3
960	PSI	LN3	FF-LN3-7	12.3
961	PSI	LN3	FF-LN3-8	12.1
962	PSI	LN3	FF-LN3-9	11.3
963	PSI	LN3	LN3-1	11.6
964	PSI	LN3	LN3-10	11.0
965	PSI	LN3	LN3-11	11.6
966	PSI	LN3	LN3-12	11.8
967	PSI	LN3	LN3-13	11.3
968	PSI	LN3	LN3-14	11.3
969	PSI	LN3	LN3-15	10.6
970	PSI	LN3	LN3-16	11.8
971	PSI	LN3	LN3-17	10.5
972	PSI	LN3	LN3-18	10.4
973	PSI	LN3	LN3-19	10.6
974	PSI	LN3	LN3-2	11.3
975	PSI	LN3	LN3-20	10.4
976	PSI	LN3	LN3-21	9.7
977	PSI	LN3	LN3-22	10.6
978	PSI	LN3	LN3-3	11.5
979	PSI	LN3	LN3-4	11.5
980	PSI	LN3	LN3-5	11.7
981	PSI	LN3	LN3-6	11.2
982	PSI	LN3	LN3-7	11.4
983	PSI	LN3	LN3-8	11.7
984	PSI	LN3	LN3-9	11.5
985	PSI	LN4	FF-LN4-1	9.0
986	PSI	LN4	FF-LN4-10	9.6
987	PSI	LN4	FF-LN4-2	.
988	PSI	LN4	FF-LN4-3	8.6

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
989	PSI	LN4	FF-LN4-4	8.7
990	PSI	LN4	FF-LN4-5	8.0
991	PSI	LN4	FF-LN4-6	8.5
992	PSI	LN4	FF-LN4-7	9.2
993	PSI	LN4	FF-LN4-8	9.3
994	PSI	LN4	FF-LN4-9	9.3
995	PSI	LN4	LN4-1	6.1
996	PSI	LN4	LN4-10	5.9
997	PSI	LN4	LN4-11	5.6
998	PSI	LN4	LN4-12	6.0
999	PSI	LN4	LN4-13	6.0
1000	PSI	LN4	LN4-14	6.1
1001	PSI	LN4	LN4-15	7.2
1002	PSI	LN4	LN4-16	4.8
1003	PSI	LN4	LN4-17	7.8
1004	PSI	LN4	LN4-18	7.9
1005	PSI	LN4	LN4-19	7.5
1006	PSI	LN4	LN4-2	6.4
1007	PSI	LN4	LN4-20	7.8
1008	PSI	LN4	LN4-21	7.9
1009	PSI	LN4	LN4-3	6.3
1010	PSI	LN4	LN4-4	6.6
1011	PSI	LN4	LN4-5	6.4
1012	PSI	LN4	LN4-6	6.7
1013	PSI	LN4	LN4-7	6.9
1014	PSI	LN4	LN4-8	6.7
1015	PSI	LN4	LN4-9	7.0
1016	PSI	LN5	FF-LN5-1	14.0
1017	PSI	LN5	FF-LN5-10	15.0
1018	PSI	LN5	FF-LN5-2	14.1
1019	PSI	LN5	FF-LN5-3	14.0
1020	PSI	LN5	FF-LN5-4	14.3
1021	PSI	LN5	FF-LN5-5	14.0
1022	PSI	LN5	FF-LN5-6	14.1
1023	PSI	LN5	FF-LN5-7	15.0
1024	PSI	LN5	FF-LN5-8	14.2
1025	PSI	LN5	FF-LN5-9	15.0
1026	PSI	LN5	LN5-1	10.9
1027	PSI	LN5	LN5-10	11.7
1028	PSI	LN5	LN5-11	11.9
1029	PSI	LN5	LN5-12	12.0
1030	PSI	LN5	LN5-13	12.1
1031	PSI	LN5	LN5-14	10.7
1032	PSI	LN5	LN5-15	11.5
1033	PSI	LN5	LN5-16	11.0
1034	PSI	LN5	LN5-17	11.5
1035	PSI	LN5	LN5-18	11.1
1036	PSI	LN5	LN5-19	11.5
1037	PSI	LN5	LN5-2	11.1
1038	PSI	LN5	LN5-20	11.6
1039	PSI	LN5	LN5-21	11.4
1040	PSI	LN5	LN5-3	11.9
1041	PSI	LN5	LN5-4	11.4
1042	PSI	LN5	LN5-5	12.2
1043	PSI	LN5	LN5-6	12.0
1044	PSI	LN5	LN5-7	11.8
1045	PSI	LN5	LN5-8	12.1
1046	PSI	LN5	LN5-9	11.8
1047	PSI	LN6	FF-LN6-1	14.1
1048	PSI	LN6	FF-LN6-10	14.0
1049	PSI	LN6	FF-LN6-2	14.0
1050	PSI	LN6	FF-LN6-3	14.0
1051	PSI	LN6	FF-LN6-4	14.1
1052	PSI	LN6	FF-LN6-5	14.1
1053	PSI	LN6	FF-LN6-6	14.1
1054	PSI	LN6	FF-LN6-7	14.0
1055	PSI	LN6	FF-LN6-8	14.0
1056	PSI	LN6	FF-LN6-9	14.0
1057	PSI	LN6	LN6-1	11.9
1058	PSI	LN6	LN6-10	11.1
1059	PSI	LN6	LN6-11	12.0
1060	PSI	LN6	LN6-12	11.4
1061	PSI	LN6	LN6-13	12.1
1062	PSI	LN6	LN6-14	12.0
1063	PSI	LN6	LN6-15	11.4
1064	PSI	LN6	LN6-16	11.2

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
1065	PSI	LN6	LN6-17	10.6
1066	PSI	LN6	LN6-18	10.8
1067	PSI	LN6	LN6-19	10.2
1068	PSI	LN6	LN6-2	12.0
1069	PSI	LN6	LN6-20	10.6
1070	PSI	LN6	LN6-21	10.9
1071	PSI	LN6	LN6-3	11.6
1072	PSI	LN6	LN6-4	10.8
1073	PSI	LN6	LN6-5	11.2
1074	PSI	LN6	LN6-6	10.7
1075	PSI	LN6	LN6-7	11.7
1076	PSI	LN6	LN6-8	10.8
1077	PSI	LN6	LN6-9	10.8
1078	PSI	RE1	FF-RE1-1	112.0
1079	PSI	RE1	FF-RE1-10	105.6
1080	PSI	RE1	FF-RE1-2	110.0
1081	PSI	RE1	FF-RE1-3	107.0
1082	PSI	RE1	FF-RE1-4	107.3
1083	PSI	RE1	FF-RE1-5	101.2
1084	PSI	RE1	FF-RE1-6	112.4
1085	PSI	RE1	FF-RE1-7	111.1
1086	PSI	RE1	FF-RE1-8	123.3
1087	PSI	RE1	FF-RE1-9	105.8
1088	PSI	RE1	RE1-1	115.1
1089	PSI	RE1	RE1-10	136.5
1090	PSI	RE1	RE1-11	127.9
1091	PSI	RE1	RE1-12	137.6
1092	PSI	RE1	RE1-13	143.5
1093	PSI	RE1	RE1-14	170.1
1094	PSI	RE1	RE1-15	120.9
1095	PSI	RE1	RE1-16	142.5
1096	PSI	RE1	RE1-17	135.3
1097	PSI	RE1	RE1-18	128.5
1098	PSI	RE1	RE1-19	89.3
1099	PSI	RE1	RE1-2	125.0
1100	PSI	RE1	RE1-20	105.5
1101	PSI	RE1	RE1-21	91.3
1102	PSI	RE1	RE1-22	116.4
1103	PSI	RE1	RE1-23	148.3
1104	PSI	RE1	RE1-24	119.6
1105	PSI	RE1	RE1-25	106.6
1106	PSI	RE1	RE1-26	136.5
1107	PSI	RE1	RE1-27	119.1
1108	PSI	RE1	RE1-3	123.1
1109	PSI	RE1	RE1-4	125.1
1110	PSI	RE1	RE1-5	134.1
1111	PSI	RE1	RE1-6	128.1
1112	PSI	RE1	RE1-7	117.4
1113	PSI	RE1	RE1-8	135.3
1114	PSI	RE1	RE1-9	114.6
1115	PSI	RE2	FF-RE2-1	20.0
1116	PSI	RE2	FF-RE2-10	20.0
1117	PSI	RE2	FF-RE2-2	19.2
1118	PSI	RE2	FF-RE2-3	20.6
1119	PSI	RE2	FF-RE2-4	19.0
1120	PSI	RE2	FF-RE2-5	16.0
1121	PSI	RE2	FF-RE2-6	20.0
1122	PSI	RE2	FF-RE2-7	16.0
1123	PSI	RE2	FF-RE2-8	20.5
1124	PSI	RE2	FF-RE2-9	17.0
1125	PSI	RE2	RE2-1	21.4
1126	PSI	RE2	RE2-10	18.7
1127	PSI	RE2	RE2-11	21.8
1128	PSI	RE2	RE2-12	20.6
1129	PSI	RE2	RE2-13	20.7
1130	PSI	RE2	RE2-14	19.1
1131	PSI	RE2	RE2-15	15.6
1132	PSI	RE2	RE2-16	20.4
1133	PSI	RE2	RE2-17	23.4
1134	PSI	RE2	RE2-18	20.5
1135	PSI	RE2	RE2-19	16.8
1136	PSI	RE2	RE2-2	17.8
1137	PSI	RE2	RE2-20	18.9
1138	PSI	RE2	RE2-21	20.1
1139	PSI	RE2	RE2-22	22.7
1140	PSI	RE2	RE2-23	23.2

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
1141	PSI	RE2	RE2-24	16.3
1142	PSI	RE2	RE2-25	16.5
1143	PSI	RE2	RE2-26	17.2
1144	PSI	RE2	RE2-27	13.7
1145	PSI	RE2	RE2-28	17.6
1146	PSI	RE2	RE2-3	22.2
1147	PSI	RE2	RE2-4	21.7
1148	PSI	RE2	RE2-5	17.9
1149	PSI	RE2	RE2-6	18.4
1150	PSI	RE2	RE2-7	21.5
1151	PSI	RE2	RE2-8	20.8
1152	PSI	RE2	RE2-9	22.7
1153	PSI	RE3	FF-RE3-1	17.0
1154	PSI	RE3	FF-RE3-10	14.3
1155	PSI	RE3	FF-RE3-2	17.0
1156	PSI	RE3	FF-RE3-3	17.0
1157	PSI	RE3	FF-RE3-4	17.0
1158	PSI	RE3	FF-RE3-5	15.2
1159	PSI	RE3	FF-RE3-6	15.2
1160	PSI	RE3	FF-RE3-7	17.3
1161	PSI	RE3	FF-RE3-8	17.4
1162	PSI	RE3	FF-RE3-9	14.1
1163	PSI	RE3	RE3-1	18.8
1164	PSI	RE3	RE3-10	25.2
1165	PSI	RE3	RE3-11	20.9
1166	PSI	RE3	RE3-12	19.8
1167	PSI	RE3	RE3-13	26.6
1168	PSI	RE3	RE3-14	19.3
1169	PSI	RE3	RE3-15	18.8
1170	PSI	RE3	RE3-16	21.0
1171	PSI	RE3	RE3-17	17.1
1172	PSI	RE3	RE3-18	19.2
1173	PSI	RE3	RE3-19	20.7
1174	PSI	RE3	RE3-2	20.6
1175	PSI	RE3	RE3-20	20.6
1176	PSI	RE3	RE3-21	22.8
1177	PSI	RE3	RE3-22	20.0
1178	PSI	RE3	RE3-23	16.3
1179	PSI	RE3	RE3-24	15.0
1180	PSI	RE3	RE3-25	14.7
1181	PSI	RE3	RE3-26	14.9
1182	PSI	RE3	RE3-27	14.8
1183	PSI	RE3	RE3-28	14.1
1184	PSI	RE3	RE3-3	20.4
1185	PSI	RE3	RE3-4	26.5
1186	PSI	RE3	RE3-5	17.0
1187	PSI	RE3	RE3-6	20.3
1188	PSI	RE3	RE3-7	23.5
1189	PSI	RE3	RE3-8	20.4
1190	PSI	RE3	RE3-9	24.4
1191	PSI	RN1	FF-RN1-1	22.2
1192	PSI	RN1	FF-RN1-10	22.2
1193	PSI	RN1	FF-RN1-2	22.3
1194	PSI	RN1	FF-RN1-3	22.2
1195	PSI	RN1	FF-RN1-4	22.3
1196	PSI	RN1	FF-RN1-5	22.3
1197	PSI	RN1	FF-RN1-6	22.3
1198	PSI	RN1	FF-RN1-7	22.1
1199	PSI	RN1	FF-RN1-8	22.0
1200	PSI	RN1	FF-RN1-9	22.1
1201	PSI	RN1	RN1-1	20.0
1202	PSI	RN1	RN1-10	20.5
1203	PSI	RN1	RN1-11	21.3
1204	PSI	RN1	RN1-12	20.1
1205	PSI	RN1	RN1-13	18.7
1206	PSI	RN1	RN1-14	19.0
1207	PSI	RN1	RN1-15	16.1
1208	PSI	RN1	RN1-16	15.6
1209	PSI	RN1	RN1-17	15.2
1210	PSI	RN1	RN1-18	16.0
1211	PSI	RN1	RN1-2	20.2
1212	PSI	RN1	RN1-3	20.9
1213	PSI	RN1	RN1-4	20.3
1214	PSI	RN1	RN1-5	20.1
1215	PSI	RN1	RN1-6	20.0
1216	PSI	RN1	RN1-7	19.7

Dry Film Thickness Results for All Panels and Free Films

OBS	Laboratory	Product ID	Panel Number	Mean Thickness (mils)
1217	PSI	RN1	RN1-8	19.8
1218	PSI	RN1	RN1-9	20.7
1219	PSI	RN2	FF-RN2-1	21.2
1220	PSI	RN2	FF-RN2-10	22.0
1221	PSI	RN2	FF-RN2-2	21.0
1222	PSI	RN2	FF-RN2-3	21.3
1223	PSI	RN2	FF-RN2-4	22.2
1224	PSI	RN2	FF-RN2-5	22.7
1225	PSI	RN2	FF-RN2-6	22.0
1226	PSI	RN2	FF-RN2-7	22.2
1227	PSI	RN2	FF-RN2-8	22.1
1228	PSI	RN2	FF-RN2-9	22.0
1229	PSI	RN2	RN2-1	20.8
1230	PSI	RN2	RN2-10	17.1
1231	PSI	RN2	RN2-11	17.0
1232	PSI	RN2	RN2-12	16.2
1233	PSI	RN2	RN2-13	20.0
1234	PSI	RN2	RN2-14	19.4
1235	PSI	RN2	RN2-15	18.1
1236	PSI	RN2	RN2-16	18.1
1237	PSI	RN2	RN2-17	18.0
1238	PSI	RN2	RN2-18	18.3
1239	PSI	RN2	RN2-19	18.3
1240	PSI	RN2	RN2-2	19.4
1241	PSI	RN2	RN2-3	20.4
1242	PSI	RN2	RN2-4	16.2
1243	PSI	RN2	RN2-5	16.8
1244	PSI	RN2	RN2-6	16.5
1245	PSI	RN2	RN2-7	16.5
1246	PSI	RN2	RN2-8	16.9
1247	PSI	RN2	RN2-9	16.9
1248	PSI	RN3	FF-RN3-1	17.0
1249	PSI	RN3	FF-RN3-10	18.0
1250	PSI	RN3	FF-RN3-2	17.7
1251	PSI	RN3	FF-RN3-3	18.0
1252	PSI	RN3	FF-RN3-4	18.1
1253	PSI	RN3	FF-RN3-5	18.0
1254	PSI	RN3	FF-RN3-6	14.3
1255	PSI	RN3	FF-RN3-7	18.0
1256	PSI	RN3	FF-RN3-8	18.2
1257	PSI	RN3	FF-RN3-9	17.8
1258	PSI	RN3	RN3-1	15.2
1259	PSI	RN3	RN3-10	19.6
1260	PSI	RN3	RN3-11	16.2
1261	PSI	RN3	RN3-12	15.7
1262	PSI	RN3	RN3-13	18.7
1263	PSI	RN3	RN3-14	12.8
1264	PSI	RN3	RN3-15	13.6
1265	PSI	RN3	RN3-16	17.4
1266	PSI	RN3	RN3-17	16.9
1267	PSI	RN3	RN3-18	14.6
1268	PSI	RN3	RN3-19	16.1
1269	PSI	RN3	RN3-2	14.8
1270	PSI	RN3	RN3-3	13.3
1271	PSI	RN3	RN3-4	13.9
1272	PSI	RN3	RN3-5	17.0
1273	PSI	RN3	RN3-6	16.9
1274	PSI	RN3	RN3-7	17.9
1275	PSI	RN3	RN3-8	15.2
1276	PSI	RN3	RN3-9	15.3

Tape Adhesion Results for Unexposed Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Adhesion Rating (0A-5A)
1	CAE	LE1	AGM 169 LE1	04/26/94	5A
2	CAE	LE1	AGM 169 LE1	04/26/94	5A
3	CAE	LE1	AGM 169 LE1	04/26/94	5A
4	CAE	LE2	AHM 195 LE2	04/26/94	5A
5	CAE	LE2	AHM 195 LE2	04/26/94	5A
6	CAE	LE2	AHM 195 LE2	04/26/94	5A
7	CAE	LE3	AIM 221 LE3	04/26/94	5A
8	CAE	LE3	AIM 221 LE3	04/26/94	5A
9	CAE	LE3	AIM 221 LE3	04/26/94	5A
10	CAE	LE4	AJM 247 LE4	04/26/94	5A
11	CAE	LE4	AJM 247 LE4	04/26/94	5A
12	CAE	LE4	AJM 247 LE4	04/26/94	5A
13	CAE	LE5	AKM 273 LE5	04/26/94	5A
14	CAE	LE5	AKM 273 LE5	04/26/94	5A
15	CAE	LE5	AKM 273 LE5	04/26/94	5A
16	CAE	LE6	ALM 299 LE6	04/26/94	1A
17	CAE	LE6	ALM 299 LE6	04/26/94	1A
18	CAE	LE6	ALM 299 LE6	04/26/94	1A
19	CAE	LN1	AAM 013 LN1	04/26/94	5A
20	CAE	LN1	AAM 013 LN1	04/26/94	5A
21	CAE	LN1	AAM 013 LN1	04/26/94	5A
22	CAE	LN2	ABM 039 LN2	04/26/94	5A
23	CAE	LN2	ABM 039 LN2	04/26/94	5A
24	CAE	LN2	ABM 039 LN2	04/26/94	5A
25	CAE	LN3	ACM 065 LN3	04/26/94	5A
26	CAE	LN3	ACM 065 LN3	04/26/94	5A
27	CAE	LN3	ACM 065 LN3	04/26/94	5A
28	CAE	LN4	ADM 091 LN4	04/26/94	5A
29	CAE	LN4	ADM 091 LN4	04/26/94	5A
30	CAE	LN4	ADM 091 LN4	04/26/94	5A
31	CAE	LN5	AEM 117 LN5	04/26/94	5A
32	CAE	LN5	AEM 117 LN5	04/26/94	5A
33	CAE	LN5	AEM 117 LN5	04/26/94	5A
34	CAE	LN6	AFM 143 LN6	04/26/94	5A
35	CAE	LN6	AFM 143 LN6	04/26/94	5A
36	CAE	LN6	AFM 143 LN6	04/26/94	5A
37	PSI	LE1	LE1-13	07/13/94	5A
38	PSI	LE1	LE1-13	07/13/94	5A
39	PSI	LE1	LE1-13	07/13/94	5A
40	PSI	LE2	LE2-13	07/13/94	4A
41	PSI	LE2	LE2-13	07/13/94	4A
42	PSI	LE2	LE2-13	07/13/94	4A
43	PSI	LE3	LE3-15	07/13/94	5A
44	PSI	LE3	LE3-15	07/13/94	5A
45	PSI	LE3	LE3-15	07/13/94	5A
46	PSI	LE4	LE4-16	07/13/94	5A
47	PSI	LE4	LE4-16	07/13/94	5A
48	PSI	LE4	LE4-16	07/13/94	5A
49	PSI	LE5	LE5-13	07/13/94	0A
50	PSI	LE5	LE5-13	07/13/94	0A
51	PSI	LE5	LE5-13	07/13/94	0A
52	PSI	LE6	LE6-15	07/13/94	0A
53	PSI	LE6	LE6-15	07/13/94	0A
54	PSI	LE6	LE6-15	07/13/94	0A
55	PSI	LN1	LN1-10	07/13/94	4A
56	PSI	LN1	LN1-10	07/13/94	5A
57	PSI	LN1	LN1-10	07/13/94	5A
58	PSI	LN2	LN2-10	07/13/94	4A
59	PSI	LN2	LN2-10	07/13/94	5A
60	PSI	LN2	LN2-10	07/13/94	5A
61	PSI	LN3	LN3-10	07/13/94	5A
62	PSI	LN3	LN3-10	07/13/94	5A
63	PSI	LN3	LN3-10	07/13/94	5A
64	PSI	LN4	LN4-10	07/13/94	0A
65	PSI	LN4	LN4-10	07/13/94	---
66	PSI	LN4	LN4-10	07/13/94	---
67	PSI	LN5	LN5-10	07/13/94	5A
68	PSI	LN5	LN5-10	07/13/94	5A
69	PSI	LN5	LN5-10	07/13/94	5A
70	PSI	LN6	LN6-10	07/13/94	5A
71	PSI	LN6	LN6-10	07/13/94	5A
72	PSI	LN6	LN6-10	07/13/94	5A

OBS	Laboratory	Product ID	Panel Number	Testing Date	Adhesion Rating (0A-5A)
1	CAE	LE1	AGX 180 LE1	05/20/94	5A
2	CAE	LE1	AGX 180 LE1	05/20/94	5A
3	CAE	LE1	AGX 180 LE1	05/20/94	5A
4	CAE	LE2	AHX 206 LE2	05/20/94	5A
5	CAE	LE2	AHX 206 LE2	05/20/94	5A
6	CAE	LE2	AHX 206 LE2	05/20/94	5A
7	CAE	LE3	AIX 232 LE3	05/20/94	5A
8	CAE	LE3	AIX 232 LE3	05/20/94	5A
9	CAE	LE3	AIX 232 LE3	05/20/94	5A
10	CAE	LE4	AJX 258 LE4	05/20/94	5A
11	CAE	LE4	AJX 258 LE4	05/20/94	5A
12	CAE	LE4	AJX 258 LE4	05/20/94	5A
13	CAE	LE5	AKX 284 LE5	05/20/94	5A
14	CAE	LE5	AKX 284 LE5	05/20/94	5A
15	CAE	LE5	AKX 284 LE5	05/20/94	5A
16	CAE	LE6	ALX 310 LE6	05/20/94	1A
17	CAE	LE6	ALX 310 LE6	05/20/94	1A
18	CAE	LE6	ALX 310 LE6	05/20/94	1A
19	CAE	LN1	AAV 022 LN1	05/20/94	5A
20	CAE	LN1	AAV 022 LN1	05/20/94	5A
21	CAE	LN1	AAV 022 LN1	05/20/94	5A
22	CAE	LN2	ABV 048 LN2	05/20/94	4A
23	CAE	LN2	ABV 048 LN2	05/20/94	4A
24	CAE	LN2	ABV 048 LN2	05/20/94	4A
25	CAE	LN3	ACV 074 LN3	05/20/94	5A
26	CAE	LN3	ACV 074 LN3	05/20/94	5A
27	CAE	LN3	ACV 074 LN3	05/20/94	5A
28	CAE	LN4	ADV 100 LN4	05/20/94	0A
29	CAE	LN4	ADV 100 LN4	05/20/94	0A
30	CAE	LN4	ADV 100 LN4	05/20/94	0A
31	CAE	LN5	AEV 126 LN5	05/20/94	5A
32	CAE	LN5	AEV 126 LN5	05/20/94	5A
33	CAE	LN5	AEV 126 LN5	05/20/94	5A
34	CAE	LN6	AFV 152 LN6	05/20/94	5A
35	CAE	LN6	AFV 152 LN6	05/20/94	5A
36	CAE	LN6	AFV 152 LN6	05/20/94	5A
37	PSI	LE1	LE1-14	05/24/94	0A
38	PSI	LE1	LE1-14	05/24/94	0A
39	PSI	LE1	LE1-14	05/24/94	0A
40	PSI	LE2	LE2-17	05/24/94	4A
41	PSI	LE2	LE2-17	05/24/94	4A
42	PSI	LE2	LE2-17	05/24/94	4A
43	PSI	LE3	LE3-17	05/24/94	0A
44	PSI	LE3	LE3-17	05/24/94	0A
45	PSI	LE3	LE3-17	05/24/94	0A
46	PSI	LE4	LE4-15	05/24/94	0A
47	PSI	LE4	LE4-15	05/24/94	0A
48	PSI	LE4	LE4-15	05/24/94	0A
49	PSI	LE5	LE5-17	05/24/94	0A
50	PSI	LE5	LE5-17	05/24/94	0A
51	PSI	LE5	LE5-17	05/24/94	0A
52	PSI	LE6	LE6-17	05/24/94	0A
53	PSI	LE6	LE6-17	05/24/94	0A
54	PSI	LE6	LE6-17	05/24/94	0A
55	PSI	LN1	LN1-11	05/24/94	0A
56	PSI	LN1	LN1-11	05/24/94	0A
57	PSI	LN1	LN1-11	05/24/94	0A
58	PSI	LN2	LN2-13	05/24/94	4A
59	PSI	LN2	LN2-13	05/24/94	4A
60	PSI	LN2	LN2-13	05/24/94	4A
61	PSI	LN3	LN3-11	05/24/94	5A
62	PSI	LN3	LN3-11	05/24/94	5A
63	PSI	LN3	LN3-11	05/24/94	5A
64	PSI	LN4	LN4-14	05/24/94	0A
65	PSI	LN4	LN4-14	05/24/94	0A
66	PSI	LN4	LN4-14	05/24/94	0A
67	PSI	LN5	LN5-11	05/24/94	5A
68	PSI	LN5	LN5-11	05/24/94	5A
69	PSI	LN5	LN5-11	05/24/94	5A
70	PSI	LN6	LN6-11	05/24/94	0A
71	PSI	LN6	LN6-11	05/24/94	0A
72	PSI	LN6	LN6-11	05/24/94	0A

Tape Adhesion Results for Weathered Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Adhesion Rating (0A-5A)
1	CAE	LE1	AGA 313 LE1	06/08/94	5A
2	CAE	LE1	AGA 313 LE1	06/08/94	5A
3	CAE	LE1	AGA 313 LE1	06/08/94	5A
4	CAE	LE2	AHA 323 LE2	06/08/94	5A
5	CAE	LE2	AHA 323 LE2	06/08/94	5A
6	CAE	LE2	AHA 323 LE2	06/08/94	5A
7	CAE	LE3	AIA 333 LE3	06/08/94	5A
8	CAE	LE3	AIA 333 LE3	06/08/94	5A
9	CAE	LE3	AIA 333 LE3	06/08/94	5A
10	CAE	LE4	AJA 343 LE4	06/08/94	5A
11	CAE	LE4	AJA 343 LE4	06/08/94	5A
12	CAE	LE4	AJA 343 LE4	06/08/94	5A
13	CAE	LE5	AKA 353 LE5	06/08/94	5A
14	CAE	LE5	AKA 353 LE5	06/08/94	5A
15	CAE	LE5	AKA 353 LE5	06/08/94	5A
16	CAE	LE6	ALA 363 LE6	06/08/94	5A
17	CAE	LE6	ALA 363 LE6	06/08/94	5A
18	CAE	LE6	ALA 363 LE6	06/08/94	5A
19	PSI	LE1	LE1-24	07/29/94	5A
20	PSI	LE1	LE1-24	07/29/94	5A
21	PSI	LE1	LE1-24	07/29/94	5A
22	PSI	LE2	LE2-24	07/29/94	5A
23	PSI	LE2	LE2-24	07/29/94	5A
24	PSI	LE2	LE2-24	07/29/94	5A
25	PSI	LE3	LE3-24	07/29/94	
26	PSI	LE3	LE3-24	07/29/94	
27	PSI	LE3	LE3-24	07/29/94	
28	PSI	LE4	LE4-24	07/29/94	
29	PSI	LE4	LE4-24	07/29/94	
30	PSI	LE4	LE4-24	07/29/94	
31	PSI	LE5	LE5-24	07/29/94	
32	PSI	LE5	LE5-24	07/29/94	
33	PSI	LE5	LE5-24	07/29/94	
34	PSI	LE6	LE6-24	07/29/94	1A
35	PSI	LE6	LE6-24	07/29/94	1A
36	PSI	LE6	LE6-24	07/29/94	1A

OBS	Laboratory	Product ID	Panel Number	Testing Date	Pull-Off Strength (psi)
1	CAE	LE1	AGN 170 LE1	06/21/94	200
2	CAE	LE1	AGO 171 LE1	06/21/94	100
3	CAE	LE1	AGP 172 LE1	06/21/94	200
4	CAE	LE2	AHN 196 LE2	06/21/94	200
5	CAE	LE2	AHO 197 LE2	06/21/94	400
6	CAE	LE2	AHP 198 LE2	06/21/94	0
7	CAE	LE3	AIN 222 LE3	06/21/94	500
8	CAE	LE3	AIO 223 LE3	06/21/94	500
9	CAE	LE3	AIP 224 LE3	06/21/94	400
10	CAE	LE4	AJN 248 LE4	06/21/94	400
11	CAE	LE4	AJO 249 LE4	06/21/94	300
12	CAE	LE4	AJP 250 LE4	06/21/94	700
13	CAE	LE5	AKN 274 LE5	06/21/94	300
14	CAE	LE5	AKO 275 LE5	06/21/94	500
15	CAE	LE5	AKP 276 LE5	06/21/94	200
16	CAE	LE6	ALN 300 LE6	06/21/94	0
17	CAE	LE6	ALO 301 LE6	06/21/94	0
18	CAE	LE6	ALP 302 LE6	06/21/94	0
19	CAE	LN1	AAN 014 LN1	06/21/94	300
20	CAE	LN1	AAO 015 LN1	06/21/94	500
21	CAE	LN1	AAP 016 LN1	06/21/94	500
22	CAE	LN2	ABN 040 LN2	06/21/94	200
23	CAE	LN2	ABO 041 LN2	06/21/94	200
24	CAE	LN2	ABP 042 LN2	06/21/94	300
25	CAE	LN3	ACN 066 LN3	06/21/94	500
26	CAE	LN3	ACO 067 LN3	06/21/94	200
27	CAE	LN3	ACP 068 LN3	06/21/94	100
28	CAE	LN4	ADN 092 LN4	06/21/94	0
29	CAE	LN4	ADO 093 LN4	06/21/94	0
30	CAE	LN4	ADP 094 LN4	06/21/94	400
31	CAE	LN5	AEN 118 LN5	06/21/94	300
32	CAE	LN5	AEO 119 LN5	06/21/94	300
33	CAE	LN5	AEP 120 LN5	06/21/94	200
34	CAE	LN6	AFN 144 LN6	06/21/94	300
35	CAE	LN6	AFO 145 LN6	06/21/94	100
36	CAE	LN6	AFP 146 LN6	06/21/94	200
37	CAE	RE1	BHM 670 RE1	06/21/94	300
38	CAE	RE1	BHN 671 RE1	06/21/94	300
39	CAE	RE1	BHO 672 RE1	06/21/94	200
40	CAE	RE2	BIM 693 RE2	06/21/94	0
41	CAE	RE2	BIN 694 RE2	06/21/94	0
42	CAE	RE2	BIO 695 RE2	06/21/94	200
43	CAE	RE3	BJM 716 RE3	06/21/94	0
44	CAE	RE3	BJN 717 RE3	06/21/94	100
45	CAE	RE3	BJO 718 RE3	06/21/94	300
46	CAE	RN1	BEM 601 RN1	06/21/94	400
47	CAE	RN1	BEN 602 RN1	06/21/94	300
48	CAE	RN1	BEO 603 RN1	06/21/94	300
49	CAE	RN2	BFM 624 RN2	06/21/94	500
50	CAE	RN2	BFN 625 RN2	06/21/94	300
51	CAE	RN2	BFO 626 RN2	06/21/94	300
52	CAE	RN3	BGM 647 RN3	06/21/94	500
53	CAE	RN3	BGN 648 RN3	06/21/94	100
54	CAE	RN3	BGO 649 RN3	06/21/94	300
55	PSI	LE1	LE1-10	06/26/94	240
56	PSI	LE1	LE1-11	06/27/94	240
57	PSI	LE1	LE1-12	06/28/94	250
58	PSI	LE2	LE2-10	06/26/94	40
59	PSI	LE2	LE2-11	06/27/94	50
60	PSI	LE2	LE2-12	06/28/94	30
61	PSI	LE3	LE3-10	06/26/94	100
62	PSI	LE3	LE3-11	06/27/94	140
63	PSI	LE3	LE3-12	06/28/94	300
64	PSI	LE4	LE4-10	06/26/94	90
65	PSI	LE4	LE4-11	06/27/94	80
66	PSI	LE4	LE4-12	06/28/94	220
67	PSI	LE5	LE5-10	06/26/94	100
68	PSI	LE5	LE5-11	06/27/94	90
69	PSI	LE5	LE5-12	06/28/94	90
70	PSI	LE6	LE6-10	06/26/94	0
71	PSI	LE6	LE6-11	06/27/94	0
72	PSI	LE6	LE6-12	06/28/94	0
73	PSI	LN1	LN1-7	06/26/94	210
74	PSI	LN1	LN1-8	06/27/94	240
75	PSI	LN1	LN1-9	06/28/94	250
76	PSI	LN2	LN2-7	06/26/94	220

OBS	Laboratory	Product ID	Panel Number	Testing Date	Pull-Off Strength (psi)
77	PSI	LN2	LN2-8	06/27/94	160
78	PSI	LN2	LN2-9	06/28/94	80
79	PSI	LN3	LN3-12	06/28/94	140
80	PSI	LN3	LN3-7	06/26/94	180
81	PSI	LN3	LN3-8	06/27/94	110
82	PSI	LN4	LN4-7	06/26/94	0
83	PSI	LN4	LN4-8	06/27/94	0
84	PSI	LN4	LN4-9	06/28/94	0
85	PSI	LN5	LN5-7	06/26/94	150
86	PSI	LN5	LN5-8	06/27/94	160
87	PSI	LN5	LN5-9	06/28/94	130
88	PSI	LN6	LN6-7	06/26/94	330
89	PSI	LN6	LN6-8	06/27/94	290
90	PSI	LN6	LN6-9	06/28/94	290
91	PSI	RE1	RE1-10	06/26/94	0
92	PSI	RE1	RE1-11	06/27/94	290
93	PSI	RE1	RE1-12	06/28/94	270
94	PSI	RE2	RE2-10	06/26/94	70
95	PSI	RE2	RE2-11	06/27/94	.
96	PSI	RE2	RE2-9	06/28/94	90
97	PSI	RE3	RE3-10	06/26/94	.
98	PSI	RE3	RE3-11	06/27/94	.
99	PSI	RE3	RE3-12	06/28/94	0
100	PSI	RN1	RN1-7	06/26/94	170
101	PSI	RN1	RN1-8	06/27/94	200
102	PSI	RN1	RN1-9	06/28/94	180
103	PSI	RN2	RN2-7	06/26/94	220
104	PSI	RN2	RN2-8	06/27/94	300
105	PSI	RN2	RN2-9	06/28/94	240
106	PSI	RN3	RN3-7	06/26/94	130
107	PSI	RN3	RN3-8	06/27/94	150
108	PSI	RN3	RN3-9	06/28/94	200

Pull Adhesion Results for Immersed (10 minute dry) Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Pull-Off Strength (psi)
1	CAE	LE1	AGS 175 LE1	06/22/94	200
2	CAE	LE1	AGU 177 LE1	06/22/94	200
3	CAE	LE2	AHS 201 LE2	06/22/94	200
4	CAE	LE2	AHU 203 LE2	06/22/94	0
5	CAE	LE3	AIS 227 LE3	06/22/94	300
6	CAE	LE3	AIU 229 LE3	06/22/94	200
7	CAE	LE4	AJS 253 LE4	06/22/94	100
8	CAE	LE4	AJU 255 LE4	06/22/94	300
9	CAE	LE5	AKS 279 LE5	06/22/94	300
10	CAE	LE5	AKU 281 LE5	06/22/94	100
11	CAE	LE6	ALS 305 LE6	06/22/94	0
12	CAE	LE6	ALU 307 LE6	06/22/94	0
13	CAE	LN1	AAS 019 LN1	06/22/94	500
14	CAE	LN1	AAU 021 LN1	06/22/94	400
15	CAE	LN2	ABS 045 LN2	06/22/94	300
16	CAE	LN2	ABU 047 LN2	06/22/94	0
17	CAE	LN3	ACS 071 LN3	06/22/94	300
18	CAE	LN3	ACU 073 LN3	06/22/94	300
19	CAE	LN4	ADS 097 LN4	06/22/94	.
20	CAE	LN4	ADU 099 LN4	06/22/94	0
21	CAE	LN5	AES 123 LN5	06/22/94	300
22	CAE	LN5	AEU 125 LN5	06/22/94	300
23	CAE	LN6	AFS 149 LN6	06/22/94	400
24	CAE	LN6	AFX 154 LN6	06/22/94	200
25	CAE	RE1	BHR 675 RE1	06/22/94	.
26	CAE	RE1	BHS 676 RE1	06/22/94	0
27	CAE	RE2	BIR 698 RE2	06/22/94	300
28	CAE	RE2	BIS 699 RE2	06/22/94	200
29	CAE	RE3	BJR 721 RE3	06/22/94	.
30	CAE	RE3	BJS 722 RE3	06/22/94	300
31	CAE	RN1	BER 606 RN1	06/22/94	100
32	CAE	RN1	BES 607 RN1	06/22/94	300
33	CAE	RN2	BFR 629 RN2	06/22/94	100
34	CAE	RN2	BFS 630 RN2	06/22/94	200
35	CAE	RN3	BGR 652 RN3	06/22/94	500
36	CAE	RN3	BGS 653 RN3	06/22/94	400

Pull Adhesion Results for Immersed (120 minute dry) Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Pull-Off Strength (psi)
1	CAE	LE1	AGN 170 LE1	06/23/94	300
2	CAE	LE2	AHN 196 LE2	06/23/94	200
3	CAE	LE3	AIN 222 LE3	06/23/94	100
4	CAE	LE4	AJN 248 LE4	06/23/94	500
5	CAE	LE5	AKN 274 LE5	06/23/94	400
6	CAE	LE6	ALN 300 LE6	06/23/94	.
7	CAE	LN1	AAN 014 LN1	06/23/94	300
8	CAE	LN2	ABN 040 LN2	06/23/94	0
9	CAE	LN3	ACN 066 LN3	06/23/94	300
10	CAE	LN4	ADN 092 LN4	06/23/94	0
11	CAE	LN5	AEN 118 LN5	06/23/94	400
12	CAE	LN6	AFN 144 LN6	06/23/94	400
13	CAE	RE1	BHM 670 RE1	06/23/94	.
14	CAE	RE2	BIM 693 RE2	06/23/94	300
15	CAE	RE3	BJM 716 RE3	06/23/94	200
16	CAE	RN1	BEM 601 RN1	06/23/94	300
17	CAE	RN2	BFM 624 RN2	06/23/94	300
18	CAE	RN3	BGM 647 RN3	06/23/94	400

Pull Adhesion Results for Weathered Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Pull-Off Strength (psi)
1	CAE	LE1	AGB 314 LE1	06/21/94	300
2	CAE	LE1	AGC 315 LE1	06/21/94	300
3	CAE	LE1	AGD 316 LE1	06/21/94	400
4	CAE	LE2	AHB 324 LE2	06/21/94	100
5	CAE	LE2	AHC 325 LE2	06/21/94	300
6	CAE	LE2	AHD 326 LE2	06/21/94	300
7	CAE	LE3	AIB 334 LE3	06/21/94	300
8	CAE	LE3	AIC 335 LE3	06/21/94	600
9	CAE	LE3	AID 336 LE3	06/21/94	600
10	CAE	LE4	AJB 344 LE4	06/21/94	500
11	CAE	LE4	AJC 345 LE4	06/21/94	200
12	CAE	LE4	AJD 346 LE4	06/21/94	100
13	CAE	LE5	AKB 354 LE5	06/21/94	500
14	CAE	LE5	AKC 355 LE5	06/21/94	200
15	CAE	LE5	AKD 356 LE5	06/21/94	400
16	CAE	LE6	ALB 364 LE6	06/21/94	0
17	CAE	LE6	ALC 365 LE6	06/21/94	0
18	CAE	LE6	ALD 366 LE6	06/21/94	0
19	CAE	RE1	BKA 728 RE1	06/21/94	.
20	CAE	RE1	BKB 729 RE1	06/21/94	0
21	CAE	RE1	BKC 730 RE1	06/21/94	.
22	CAE	RE2	BLA 738 RE2	06/21/94	0
23	CAE	RE2	BLB 739 RE2	06/21/94	0
24	CAE	RE2	BLC 740 RE2	06/21/94	0
25	CAE	RE3	BMA 748 RE3	06/21/94	0
26	CAE	RE3	BMB 749 RE3	06/21/94	0
27	CAE	RE3	BMC 750 RE3	06/21/94	0
28	PSI	LE1	LE1-21	06/28/94	210
29	PSI	LE1	LE1-22	06/28/94	220
30	PSI	LE1	LE1-23	06/28/94	330
31	PSI	LE2	LE2-21	06/28/94	140
32	PSI	LE2	LE2-22	06/28/94	.
33	PSI	LE2	LE2-23	06/28/94	90
34	PSI	LE3	LE3-21	06/28/94	290
35	PSI	LE3	LE3-22	06/28/94	230
36	PSI	LE3	LE3-23	06/28/94	150
37	PSI	LE4	LE4-21	06/28/94	130
38	PSI	LE4	LE4-22	06/28/94	220
39	PSI	LE4	LE4-23	06/28/94	100
40	PSI	LE5	LE5-21	06/28/94	240
41	PSI	LE5	LE5-22	06/28/94	280
42	PSI	LE5	LE5-23	06/28/94	300
43	PSI	LE6	LE6-21	06/28/94	0
44	PSI	LE6	LE6-22	06/28/94	0
45	PSI	LE6	LE6-23	06/28/94	0
46	PSI	RE1	RE1-19	06/28/94	270
47	PSI	RE1	RE1-20	06/28/94	160
48	PSI	RE1	RE1-21	06/28/94	290
49	PSI	RE2	RE2-19	06/28/94	10
50	PSI	RE2	RE2-20	06/28/94	20
51	PSI	RE2	RE2-21	06/28/94	0
52	PSI	RE3	RE3-19	06/28/94	10
53	PSI	RE3	RE3-20	06/28/94	0
54	PSI	RE3	RE3-21	06/28/94	10

OBS	Laboratory	Product ID	Panel Number	Testing Date	End Point (cycles)
1	CAE	LE1	AGA 157 LE1	04/12/94	5000
2	CAE	LE1	AGB 158 LE1	04/21/94	5000
3	CAE	LE1	AGC 159 LE1	05/05/94	5000
4	CAE	LE2	AHA 183 LE2	04/08/94	2192
5	CAE	LE2	AHB 184 LE2	04/20/94	2169
6	CAE	LE2	AHC 185 LE2	05/13/94	1940
7	CAE	LE3	AIA 209 LE3	04/21/94	3895
8	CAE	LE3	AIB 210 LE3	04/19/94	3689
9	CAE	LE3	AIC 211 LE3	05/09/94	5000
10	CAE	LE4	AJA 235 LE4	04/07/94	5000
11	CAE	LE4	AJB 236 LE4	04/08/94	5000
12	CAE	LE4	AJC 237 LE4	05/12/94	5000
13	CAE	LE5	AKA 261 LE5	04/07/94	4214
14	CAE	LE5	AKB 262 LE5	04/15/94	4399
15	CAE	LE5	AKC 263 LE5	05/11/94	5000
16	CAE	LE6	ALA 287 LE6	04/14/94	2624
17	CAE	LE6	ALB 288 LE6	04/14/94	2587
18	CAE	LE6	ALC 289 LE6	04/26/94	2226
19	CAE	LN1	AAA 001 LN1	04/07/94	1791
20	CAE	LN1	AAB 002 LN1	04/14/94	2144
21	CAE	LN1	ACC 003 LN1	04/22/94	2210
22	CAE	LN2	ABA 027 LN2	04/12/94	887
23	CAE	LN2	ABB 028 LN2	04/25/94	1144
24	CAE	LN2	ABC 029 LN2	05/13/94	936
25	CAE	LN3	ACA 053 LN3	04/19/94	5000
26	CAE	LN3	ACB 054 LN3	04/06/94	5000
27	CAE	LN3	ACC 055 LN3	05/11/94	5000
28	CAE	LN4	ADA 079 LN4	04/07/94	164
29	CAE	LN4	ADB 080 LN4	04/07/94	154
30	CAE	LN4	ADC 081 LN4	04/27/94	156
31	CAE	LN5	AEA 105 LN5	04/15/94	5000
32	CAE	LN5	AEB 106 LN5	04/07/94	5000
33	CAE	LN5	AEC 107 LN5	04/27/94	5000
34	CAE	LN6	AFA 131 LN6	04/20/94	5000
35	CAE	LN6	AFB 132 LN6	04/14/94	5000
36	CAE	LN6	AFC 133 LN6	05/12/94	5000
37	CAE	RE1	BHA 658 RE1	04/13/94	.
38	CAE	RE1	BHB 659 RE1	04/12/94	5000
39	CAE	RE1	BHC 660 RE1	04/26/94	5000
40	CAE	RE2	BIA 681 RE2	04/20/94	5000
41	CAE	RE2	BIB 682 RE2	04/12/94	5000
42	CAE	RE2	BIC 683 RE2	05/03/94	5000
43	CAE	RE3	BJA 704 RE3	04/06/94	5000
44	CAE	RE3	BJB 705 RE3	04/21/94	5000
45	CAE	RE3	BJC 706 RE3	05/09/94	5000
46	CAE	RN1	BEA 589 RN1	04/14/94	5000
47	CAE	RN1	BEB 590 RN1	04/22/94	5000
48	CAE	RN1	BEC 591 RN1	05/17/94	5000
49	CAE	RN2	BFA 612 RN2	04/18/94	5000
50	CAE	RN2	BFB 613 RN2	04/20/94	5000
51	CAE	RN2	BFC 614 RN2	05/06/94	5000
52	CAE	RN3	BGA 635 RN3	04/11/94	5000
53	CAE	RN3	BGB 636 RN3	04/07/94	5000
54	CAE	RN3	BGC 637 RN3	04/25/94	5000
55	PSI	LE1	LE1-1	06/08/94	5000
56	PSI	LE1	LE1-2	06/21/94	5000
57	PSI	LE1	LE1-3	05/19/94	4940
58	PSI	LE2	LE2-1	06/27/94	4600
59	PSI	LE2	LE2-2	06/07/94	3200
60	PSI	LE2	LE2-3	05/19/94	2400
61	PSI	LE3	LE3-1	05/20/94	5000
62	PSI	LE3	LE3-2	06/06/94	5000
63	PSI	LE3	LE3-3	06/22/94	5000
64	PSI	LE4	LE4-1	05/18/94	5000
65	PSI	LE4	LE4-2	06/01/94	5000
66	PSI	LE4	LE4-3	06/24/94	5000
67	PSI	LE5	LE5-1	05/17/94	5000
68	PSI	LE5	LE5-2	06/03/94	5000
69	PSI	LE5	LE5-3	06/23/94	5000
70	PSI	LE6	LE6-1	05/20/94	4400
71	PSI	LE6	LE6-2	06/02/94	4182
72	PSI	LE6	LE6-3	06/13/94	5000
73	PSI	LN1	LN1-1	05/17/94	5000
74	PSI	LN1	LN1-2	06/03/94	5000
75	PSI	LN1	LN1-3	06/10/94	5000
76	PSI	LN2	LN2-1	06/29/94	2671

OBS	Laboratory	Product ID	Panel Number	Testing Date	End Point (cycles)
77	PSI	LN2	LN2-2	06/10/94	2508
78	PSI	LN2	LN2-3	05/19/94	1953
79	PSI	LN3	LN3-1	05/24/94	5000
80	PSI	LN3	LN3-2	05/27/94	5000
81	PSI	LN3	LN3-3	06/22/94	5000
82	PSI	LN4	LN4-1	05/18/94	1021
83	PSI	LN4	LN4-2	05/31/94	800
84	PSI	LN4	LN4-3	06/14/94	892
85	PSI	LN5	LN5-1	05/31/94	5000
86	PSI	LN5	LN5-2	06/23/94	3800
87	PSI	LN5	LN5-3	06/14/94	5000
88	PSI	LN6	LN6-1	05/25/94	5000
89	PSI	LN6	LN6-2	06/02/94	5000
90	PSI	LN6	LN6-3	06/27/94	5000
91	PSI	RE1	RE1-1	05/20/94	5000
92	PSI	RE1	RE1-2	06/01/94	5000
93	PSI	RE1	RE1-3	06/14/94	5000
94	PSI	RE2	RE2-1	05/24/94	5000
95	PSI	RE2	RE2-2	06/01/94	5000
96	PSI	RE2	RE2-3	06/15/94	5000
97	PSI	RE3	RE3-1	05/13/94	5000
98	PSI	RE3	RE3-2	06/07/94	5000
99	PSI	RE3	RE3-3	06/22/94	5000
100	PSI	RN1	RN1-1	06/09/94	5000
101	PSI	RN1	RN1-2	06/29/94	5000
102	PSI	RN1	RN1-3	06/23/94	5000
103	PSI	RN2	RN2-1	06/23/94	5000
104	PSI	RN2	RN2-2	06/07/94	5000
105	PSI	RN2	RN2-3	06/21/94	5000
106	PSI	RN3	RN3-1	05/19/94	5000
107	PSI	RN3	RN3-2	05/31/94	5000
108	PSI	RN3	RN3-3	06/13/94	5000

OBS	Laboratory	Product ID	Panel Number	Testing Date	End Point (cycles)
1	CAE	LE1	AGH 320 LE1	05/17/94	5000
2	CAE	LE1	AGI 321 LE1	.	.
3	CAE	LE1	AGK 322 LE1	05/20/94	4594
4	CAE	LE2	AHH 330 LE2	.	.
5	CAE	LE2	AHI 331 LE2	.	.
6	CAE	LE2	AHK 332 LE2	05/23/94	4031
7	CAE	LE3	AIH 340 LE3	05/23/94	5000
8	CAE	LE3	AII 341 LE3	06/03/94	5000
9	CAE	LE3	AIK 342 LE3	05/18/94	5000
10	CAE	LE4	AJH 350 LE4	05/18/94	5000
11	CAE	LE4	AJI 351 LE4	06/02/94	5000
12	CAE	LE4	AJK 352 LE4	.	.
13	CAE	LE5	AKH 360 LE5	.	.
14	CAE	LE5	AKI 361 LE5	06/07/94	5000
15	CAE	LE5	AKK 362 LE5	06/08/94	5000
16	CAE	LE6	ALH 370 LE6	05/20/94	5000
17	CAE	LE6	ALI 371 LE6	06/06/94	5000
18	CAE	LE6	ALK 372 LE6	05/24/94	5000
19	CAE	RE1	BKH 735 RE1	05/18/94	5000
20	CAE	RE1	BKI 736 RE1	06/06/94	5000
21	CAE	RE1	BKJ 737 RE1	05/18/94	5000
22	CAE	RE2	BLH 745 RE2	05/19/94	5000
23	CAE	RE2	BLI 746 RE2	06/03/94	5000
24	CAE	RE2	BLJ 747 RE2	05/19/94	5000
25	CAE	RE3	BMH 755 RE3	05/20/94	5000
26	CAE	RE3	BMI 756 RE3	06/02/94	5000
27	CAE	RE3	BMJ 757 RE3	05/20/94	5000
28	PSI	LE1	LE1-4	.	.
29	PSI	LE1	LE1-5	.	.
30	PSI	LE1	LE1-6	.	.
31	PSI	LE2	LE2-4	.	.
32	PSI	LE2	LE2-5	.	.
33	PSI	LE2	LE2-6	.	.
34	PSI	LE3	LE3-4	.	.
35	PSI	LE3	LE3-5	07/01/94	5000
36	PSI	LE3	LE3-6	.	.
37	PSI	LE4	LE4-4	.	.
38	PSI	LE4	LE4-5	.	.
39	PSI	LE4	LE4-6	.	.
40	PSI	LE5	LE5-4	06/30/94	5000
41	PSI	LE5	LE5-5	.	.
42	PSI	LE5	LE5-6	07/06/94	5000
43	PSI	LE6	LE6-4	.	.
44	PSI	LE6	LE6-5	.	.
45	PSI	LE6	LE6-6	.	.
46	PSI	RE1	RE1-4	06/28/94	5000
47	PSI	RE1	RE1-5	.	.
48	PSI	RE1	RE1-6	07/05/94	5000
49	PSI	RE2	RE2-4	06/30/94	5000
50	PSI	RE2	RE2-5	07/05/94	5000
51	PSI	RE2	RE2-6	07/06/94	5000
52	PSI	RE3	RE3-4	07/01/94	5000
53	PSI	RE3	RE3-5	07/05/94	5000
54	PSI	RE3	RE3-6	.	.

OBS	Laboratory	Product ID	Panel Number	Testing Date	Crack Length (inches)
1	CAE	LE1	AGH 164 LE1	04/26/94	0.00
2	CAE	LE1	AGI 165 LE1	04/26/94	0.00
3	CAE	LE1	AGJ 166 LE1	04/26/94	0.00
4	CAE	LE2	AHH 190 LE2	04/26/94	0.00
5	CAE	LE2	AHI 191 LE2	04/26/94	0.00
6	CAE	LE2	AHJ 192 LE2	04/26/94	0.00
7	CAE	LE3	AIH 216 LE3	04/26/94	0.00
8	CAE	LE3	AII 217 LE3	04/26/94	0.00
9	CAE	LE3	AIJ 218 LE3	04/26/94	0.00
10	CAE	LE4	AJH 242 LE4	04/26/94	0.00
11	CAE	LE4	AJI 243 LE4	04/26/94	0.00
12	CAE	LE4	AJJ 244 LE4	04/26/94	0.00
13	CAE	LE5	AKH 268 LE5	04/26/94	0.00
14	CAE	LE5	AKI 269 LE5	04/26/94	0.00
15	CAE	LE5	AKJ 270 LE5	04/26/94	0.00
16	CAE	LE6	ALH 294 LE6	04/26/94	0.00
17	CAE	LE6	ALI 295 LE6	04/26/94	0.00
18	CAE	LE6	ALJ 296 LE6	04/26/94	0.00
19	CAE	LN1	AAH 008 LN1	04/26/94	0.00
20	CAE	LN1	AAI 009 LN1	04/26/94	0.00
21	CAE	LN1	AAJ 010 LN1	04/26/94	0.00
22	CAE	LN2	ABH 034 LN2	04/26/94	0.19
23	CAE	LN2	ABI 035 LN2	04/26/94	0.31
24	CAE	LN2	ABJ 036 LN2	04/26/94	0.19
25	CAE	LN3	ACH 060 LN3	04/26/94	0.00
26	CAE	LN3	ACI 061 LN3	04/26/94	0.00
27	CAE	LN3	ACJ 062 LN3	04/26/94	0.00
28	CAE	LN4	ADH 086 LN4	04/26/94	0.00
29	CAE	LN4	ADI 087 LN4	04/26/94	0.00
30	CAE	LN4	ADJ 088 LN4	04/26/94	0.00
31	CAE	LN5	AEH 112 LN5	04/26/94	0.00
32	CAE	LN5	AEI 113 LN5	04/26/94	0.00
33	CAE	LN5	AEJ 114 LN5	04/26/94	0.00
34	CAE	LN6	AFH 138 LN6	04/26/94	0.00
35	CAE	LN6	AFI 139 LN6	04/26/94	0.00
36	CAE	LN6	AFJ 140 LN6	04/26/94	0.00
37	CAE	RE1	BHH 665 RE1	04/26/94	.
38	CAE	RE1	BHI 666 RE1	04/26/94	.
39	CAE	RE1	BHJ 667 RE1	04/26/94	.
40	CAE	RE2	BIH 688 RE2	04/26/94	3.00
41	CAE	RE2	BII 689 RE2	04/26/94	3.00
42	CAE	RE2	BIJ 690 RE2	04/26/94	3.00
43	CAE	RE3	BJH 711 RE3	04/26/94	3.00
44	CAE	RE3	BJI 712 RE3	04/26/94	3.00
45	CAE	RE3	BJJ 713 RE3	04/26/94	3.00
46	CAE	RN1	BEH 596 RN1	04/26/94	0.00
47	CAE	RN1	BEI 597 RN1	04/26/94	0.00
48	CAE	RN1	BEJ 598 RN1	04/26/94	0.00
49	CAE	RN2	BFH 619 RN2	04/26/94	0.00
50	CAE	RN2	BFI 620 RN2	04/26/94	0.00
51	CAE	RN2	BFJ 621 RN2	04/26/94	0.00
52	CAE	RN3	BGH 642 RN3	04/26/94	0.00
53	CAE	RN3	BGI 643 RN3	04/26/94	0.00
54	CAE	RN3	BGJ 644 RN3	04/26/94	0.00
55	PSI	LE1	LE1-7	05/24/94	0.00
56	PSI	LE1	LE1-8	05/24/94	0.00
57	PSI	LE1	LE1-9	05/24/94	0.00
58	PSI	LE2	LE2-7	05/24/94	0.00
59	PSI	LE2	LE2-8	05/24/94	0.00
60	PSI	LE2	LE2-9	05/24/94	0.00
61	PSI	LE3	LE3-7	05/24/94	0.00
62	PSI	LE3	LE3-8	05/24/94	0.00
63	PSI	LE3	LE3-9	05/24/94	0.00
64	PSI	LE4	LE4-7	05/24/94	0.00
65	PSI	LE4	LE4-8	05/24/94	0.00
66	PSI	LE4	LE4-9	05/24/94	0.00
67	PSI	LE5	LE5-7	05/24/94	0.00
68	PSI	LE5	LE5-8	05/24/94	0.00
69	PSI	LE5	LE5-9	05/24/94	0.00
70	PSI	LE6	LE6-7	05/24/94	0.00
71	PSI	LE6	LE6-8	05/24/94	0.00
72	PSI	LE6	LE6-9	05/24/94	0.00
73	PSI	LN1	LN1-4	05/24/94	0.00
74	PSI	LN1	LN1-5	05/24/94	0.00
75	PSI	LN1	LN1-6	05/24/94	0.00
76	PSI	LN2	LN2-4	05/24/94	0.27

OBS	Laboratory	Product ID	Panel Number	Testing Date	Crack Length (inches)
77	PSI	LN2	LN2-5	05/24/94	0.31
78	PSI	LN2	LN2-6	05/24/94	0.43
79	PSI	LN3	LN3-4	05/24/94	0.00
80	PSI	LN3	LN3-5	05/24/94	0.00
81	PSI	LN3	LN3-6	05/24/94	0.00
82	PSI	LN4	LN4-4	05/24/94	0.00
83	PSI	LN4	LN4-5	05/24/94	0.00
84	PSI	LN4	LN4-6	05/24/94	0.00
85	PSI	LN5	LN5-4	05/24/94	0.00
86	PSI	LN5	LN5-5	05/24/94	0.00
87	PSI	LN5	LN5-6	05/24/94	0.00
88	PSI	LN6	LN6-4	05/24/94	0.00
89	PSI	LN6	LN6-5	05/24/94	0.00
90	PSI	LN6	LN6-6	05/24/94	0.00
91	PSI	RE1	RE1-7	05/24/94	.
92	PSI	RE1	RE1-8	05/24/94	.
93	PSI	RE1	RE1-9	05/24/94	.
94	PSI	RE2	RE2-7	05/24/94	6.00
95	PSI	RE2	RE2-8	05/24/94	6.00
96	PSI	RE2	RE2-9	05/24/94	6.00
97	PSI	RE3	RE3-3	05/24/94	6.00
98	PSI	RE3	RE3-7	05/24/94	6.00
99	PSI	RE3	RE3-9	05/24/94	6.00
100	PSI	RN1	RN1-4	05/24/94	0.00
101	PSI	RN1	RN1-5	05/24/94	0.00
102	PSI	RN1	RN1-6	05/24/94	0.00
103	PSI	RN2	RN2-4	05/24/94	0.00
104	PSI	RN2	RN2-5	05/24/94	0.00
105	PSI	RN2	RN2-6	05/24/94	0.00
106	PSI	RN3	RN3-4	05/24/94	0.00
107	PSI	RN3	RN3-5	05/24/94	0.00
108	PSI	RN3	RN3-6	05/24/94	0.00

OBS	Laboratory	Product ID	Panel Number	Testing Date	Crack Length (inches)
1	CAE	LE1	AGE 317 LE1	05/17/94	0.00
2	CAE	LE1	AGF 318 LE1	05/17/94	0.00
3	CAE	LE1	AGG 319 LE1	05/17/94	0.00
4	CAE	LE2	AHE 327 LE2	05/17/94	0.00
5	CAE	LE2	AHF 328 LE2	05/17/94	0.00
6	CAE	LE2	AHG 329 LE2	05/17/94	0.00
7	CAE	LE3	AIE 337 LE3	05/17/94	0.00
8	CAE	LE3	AIF 338 LE3	05/17/94	0.00
9	CAE	LE3	AIG 339 LE3	05/17/94	0.00
10	CAE	LE4	AJE 347 LE4	05/17/94	0.00
11	CAE	LE4	AJF 348 LE4	05/17/94	0.00
12	CAE	LE4	AJG 349 LE4	05/17/94	0.00
13	CAE	LE5	AKE 357 LE5	05/17/94	0.00
14	CAE	LE5	AKF 358 LE5	05/17/94	0.00
15	CAE	LE5	AKG 359 LE5	05/17/94	0.00
16	CAE	LE6	ALF 368 LE6	05/17/94	1.50
17	CAE	LE6	ALG 369 LE6	05/17/94	1.94
18	CAE	LE6	ALV 308 LE6	05/17/94	1.56
19	CAE	RE1	BKD 731 RE1	05/17/94	.
20	CAE	RE1	BKE 732 RE1	05/17/94	.
21	CAE	RE1	BKF 733 RE1	05/17/94	.
22	CAE	RE2	BLD 741 RE2	05/17/94	3.00
23	CAE	RE2	BLE 742 RE2	05/17/94	3.00
24	CAE	RE2	BLF 743 RE2	05/17/94	.
25	CAE	RE3	BMD 751 RE3	05/17/94	.
26	CAE	RE3	BME 752 RE3	05/17/94	3.00
27	CAE	RE3	BMF 753 RE3	05/17/94	.
28	PSI	LE1	LE1-18	05/23/94	0.00
29	PSI	LE1	LE1-19	05/24/94	0.00
30	PSI	LE1	LE1-20	05/24/94	0.00
31	PSI	LE2	LE2-18	05/24/94	0.00
32	PSI	LE2	LE2-19	05/24/94	0.00
33	PSI	LE2	LE2-20	05/23/94	0.00
34	PSI	LE3	LE3-18	05/23/94	0.00
35	PSI	LE3	LE3-19	05/24/94	0.00
36	PSI	LE3	LE3-20	05/24/94	0.00
37	PSI	LE4	LE4-18	05/24/94	0.00
38	PSI	LE4	LE4-19	05/24/94	0.00
39	PSI	LE4	LE4-20	05/23/94	0.00
40	PSI	LE5	LE5-18	05/24/94	0.00
41	PSI	LE5	LE5-19	05/23/94	0.00
42	PSI	LE5	LE5-20	05/24/94	0.00
43	PSI	LE6	LE6-18	05/23/94	0.13
44	PSI	LE6	LE6-19	05/24/94	0.00
45	PSI	LE6	LE6-20	05/24/94	0.75
46	PSI	RE1	RE1-16	05/23/94	.
47	PSI	RE1	RE1-17	05/24/94	.
48	PSI	RE1	RE1-18	05/24/94	.
49	PSI	RE2	RE2-16	05/24/94	6.00
50	PSI	RE2	RE2-17	05/24/94	6.00
51	PSI	RE2	RE2-18	05/23/94	6.00
52	PSI	RE3	RE3-16	05/24/94	6.00
53	PSI	RE3	RE3-17	05/24/94	.
54	PSI	RE3	RE3-18	05/23/94	6.00

Impact Resistance Results for Unexposed Panels

OBS	Laboratory	Product ID	End Point (ft-lbs)
1	CAE	LE1	160
2	CAE	LE2	152
3	CAE	LE3	160
4	CAE	LE4	124
5	CAE	LE5	160
6	CAE	LE6	80
7	CAE	LN1	160
8	CAE	LN2	40
9	CAE	LN3	160
10	CAE	LN4	24
11	CAE	LN5	160
12	CAE	LN6	160
13	CAE	RE1	160
14	CAE	RE2	20
15	CAE	RE3	16
16	CAE	RN1	160
17	CAE	RN2	160
18	CAE	RN3	116
19	PSI	LE1	52
20	PSI	LE2	120
21	PSI	LE3	152
22	PSI	LE4	124
23	PSI	LE5	124
24	PSI	LE6	56
25	PSI	LN1	128
26	PSI	LN2	24
27	PSI	LN3	136
28	PSI	LN4	24
29	PSI	LN5	156
30	PSI	LN6	156
31	PSI	RE1	24
32	PSI	RE2	16
33	PSI	RE3	16
34	PSI	RN1	160
35	PSI	RN2	160
36	PSI	RN3	34

OBS	Laboratory	Product ID	Panel Number	Testing Date	Endpoint (cycles)	Weight Lost After 1000 Cycles (g)	Weight Lost At End Point (g)	Wear Index (g/1000 cycles)
1	CAE	LE1	AGK 167 LE1	05/21/94	1144	0.42	0.48	0.42
2	CAE	LE1	AGL 168 LE1	06/02/94	1096	0.43	0.48	0.44
3	CAE	LE2	AHK 193 LE2	05/19/94	2500	0.20	0.55	0.22
4	CAE	LE2	AHL 194 LE2	05/28/94	2072	0.20	0.58	0.28
5	CAE	LE3	AIK 219 LE3	05/20/94	2591	0.17	0.54	0.21
6	CAE	LE3	AIL 220 LE3	05/28/94	3657	0.17	0.62	0.17
7	CAE	LE4	AJK 245 LE4	05/14/94	3000	0.15	0.46	0.15
8	CAE	LE4	AJL 246 LE4	05/23/94	3251	0.16	0.53	0.16
9	CAE	LE5	AKK 271 LE5	05/15/94	3921	0.17	0.61	0.16
10	CAE	LE5	AKL 272 LE5	06/04/94	3622	0.17	0.56	0.16
11	CAE	LE6	ALK 297 LE6	05/17/94	1867	0.32	0.61	0.33
12	CAE	LE6	ALL 298 LE6	06/01/94	2517	0.26	0.71	0.28
13	CAE	LN1	AAK 011 LN1	05/21/94	3500	0.10	0.43	0.12
14	CAE	LN1	AAL 012 LN1	05/24/94	2704	0.12	0.45	0.17
15	CAE	LN2	ABK 037 LN2	05/23/94	4431	0.18	0.67	0.15
16	CAE	LN2	ABL 038 LN2	05/30/94	3961	0.19	0.72	0.18
17	CAE	LN3	ACK 063 LN3	05/17/94	4802	0.22	0.97	0.20
18	CAE	LN3	ACL 064 LN3	05/29/94	4000	0.18	0.77	0.19
19	CAE	LN4	ADL 090 LN4	05/31/94	1773	0.27	0.48	0.27
20	CAE	LN4	ADX 089 LN4	05/17/94	1500	0.25	0.37	0.25
21	CAE	LN5	AEK 115 LN5	05/20/94	5000	0.19	0.75	0.15
22	CAE	LN5	AEL 116 LN5	05/31/94	5000	0.16	0.76	0.15
23	CAE	LN6	AFK 141 LN6	05/14/94	5000	0.11	0.73	0.15
24	CAE	LN6	AFL 142 LN6	05/24/94	5000	0.16	0.80	0.16
25	CAE	RE1	BHK 668 RE1	05/19/94	5000	0.15	0.48	0.10
26	CAE	RE1	BHL 669 RE1	06/02/94	5000	0.19	0.48	0.10
27	CAE	RE2	BIK 691 RE2	05/21/94	5000	0.14	0.55	0.11
28	CAE	RE2	BIL 692 RE2	06/01/94	5000	0.16	0.54	0.11
29	CAE	RE3	BJK 714 RE3	05/19/94	5000	0.13	0.51	0.10
30	CAE	RE3	BJL 715 RE3	06/03/94	5000	0.12	0.48	0.10
31	CAE	RN1	BEK 599 RN1	05/15/94	5000	0.12	0.59	0.12
32	CAE	RN1	BEL 600 RN1	05/29/94	5000	0.10	0.39	0.08
33	CAE	RN2	BFK 622 RN2	05/20/94	5000	0.17	0.60	0.12
34	CAE	RN2	BFL 623 RN2	06/02/94	5000	0.09	0.32	0.06
35	CAE	RN3	BGK 645 RN3	05/14/94	.	0.13	.	.
36	CAE	RN3	BGL 646 RN3	06/01/94	.	0.17	.	.
37	PSI	LE1	LE1-25	06/06/94	1000	0.55	0.55	0.55
38	PSI	LE1	LE1-26	07/27/94	600	.	0.35	0.59
39	PSI	LE2	LE2-25	05/24/94	3250	0.22	0.66	0.20
40	PSI	LE2	LE2-26	06/26/94	2100	0.28	0.57	0.27
41	PSI	LE3	LE3-25	06/05/94	3350	0.15	0.45	0.13
42	PSI	LE3	LE3-26	06/26/94	2800	0.18	0.50	0.18
43	PSI	LE4	LE4-25	05/18/94	3500	0.14	0.48	0.14
44	PSI	LE4	LE4-26	06/25/94	2600	0.20	0.52	0.20
45	PSI	LE5	LE5-25	05/20/94	5000	0.07	0.22	0.04
46	PSI	LE5	LE5-26	07/27/94	3850	0.11	0.47	0.12
47	PSI	LE6	LE6-25	05/24/94	1900	0.25	0.71	0.37
48	PSI	LE6	LE6-26	07/25/94	2000	0.29	0.71	0.36
49	PSI	LN1	LN1-15	06/06/94	3700	0.13	0.49	0.13
50	PSI	LN1	LN1-16	06/25/94	4100	0.15	0.60	0.15
51	PSI	LN2	LN2-15	06/06/94	2100	0.28	0.61	0.29
52	PSI	LN2	LN2-16	06/28/94	1900	0.27	0.52	0.27
53	PSI	LN3	LN3-15	05/24/94	5000	0.12	0.37	0.07
54	PSI	LN3	LN3-16	06/28/94	5000	0.16	1.33	0.27
55	PSI	LN4	LN4-15	05/24/94	2420	0.29	0.65	0.27
56	PSI	LN4	LN4-16	07/21/94	1350	0.28	0.37	0.28
57	PSI	LN5	LN5-15	05/25/94	5000	0.11	0.50	0.10
58	PSI	LN5	LN5-16	07/21/94	5000	0.08	0.34	0.07
59	PSI	LN6	LN6-15	05/18/94	5000	0.16	0.73	0.15
60	PSI	LN6	LN6-16	06/25/94	5000	0.23	0.90	0.18
61	PSI	RE1	RE1-22	05/25/94	.	0.15	.	.
62	PSI	RE1	RE1-23	07/25/94	.	.	.	.
63	PSI	RE2	RE2-22	06/06/94	5000	0.23	0.74	0.15
64	PSI	RE2	RE2-23	07/25/94	5000	0.16	0.55	0.11
65	PSI	RE3	RE3-22	05/25/94	5000	0.20	0.70	0.14
66	PSI	RE3	RE3-23	07/27/94	5000	0.20	0.95	0.19
67	PSI	RN1	RN1-13	06/05/94	5000	0.06	0.34	0.07
68	PSI	RN1	RN1-14	06/26/94	5000	0.09	0.43	0.09
69	PSI	RN2	RN2-13	05/20/94	5000	0.01	0.06	0.01
70	PSI	RN2	RN2-14	07/25/94	5000	0.02	0.07	0.01
71	PSI	RN3	RN3-13	05/20/94	5000	0.19	0.81	0.16
72	PSI	RN3	RN3-14	07/25/94	5000	0.20	0.74	0.15

Viscoelasticity Results for Unexposed Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Tensile Strength (psi)	Elongation (%)	Stiffness (psi)
1	CAE	LE1	ASD 448 LE1	06/18/94	655	9	527
2	CAE	LE1	ASH 452 LE1	06/23/94	658	10	520
3	CAE	LE1	ASJ 454 LE1	06/25/94	680	14	527
4	CAE	LE1	ASK 455 LE1	06/20/94	656	6	590
5	CAE	LE1	ASL 456 LE1	06/22/94	654	11	512
6	CAE	LE2	ATB 458 LE2	06/15/94	1039	19	644
7	CAE	LE2	ATC 459 LE2	06/17/94	982	19	627
8	CAE	LE2	ATE 461 LE2	06/20/94	996	16	611
9	CAE	LE2	ATH 464 LE2	06/22/94	967	18	593
10	CAE	LE2	ATJ 466 LE2	06/25/94	984	15	611
11	CAE	LE3	AUB 470 LE3	06/17/94	412	362	75
12	CAE	LE3	AUC 471 LE3	06/17/94	325	502	99
13	CAE	LE3	AUD 472 LE3	06/18/94	312	505	56
14	CAE	LE3	AUG 475 LE3	06/22/94	379	486	51
15	CAE	LE3	AUJ 478 LE3	06/25/94	337	538	73
16	CAE	LE4	AVD 484 LE4	06/18/94	822	254	161
17	CAE	LE4	AVE 485 LE4	06/18/94	841	264	150
18	CAE	LE4	AVF 486 LE4	06/20/94	783	241	136
19	CAE	LE4	AVG 487 LE4	06/22/94	794	258	151
20	CAE	LE4	AVH 488 LE4	06/23/94	810	249	
21	CAE	LE5	AWB 494 LE5	06/15/94	379	402	73
22	CAE	LE5	AWC 495 LE5	06/17/94	403	407	78
23	CAE	LE5	AWD 496 LE5	06/18/94	410	374	67
24	CAE	LE5	AWE 497 LE5	06/20/94	403	463	78
25	CAE	LE5	AWJ 502 LE5	06/25/94	436	450	69
26	CAE	LE6	AXA 505 LE6	06/15/94	813	253	154
27	CAE	LE6	AXD 508 LE6	06/18/94	647	17	477
28	CAE	LE6	AXF 510 LE6	06/20/94	622	17	449
29	CAE	LE6	AXJ 514 LE6	06/25/94	602	17	433
30	CAE	LE6	AXL 516 LE6	06/17/94	638	12	470
31	CAE	LN1	AMC 375 LN1	06/17/94	627	170	390
32	CAE	LN1	AME 377 LN1	06/18/94	635	182	391
33	CAE	LN1	AMF 378 LN1	06/20/94	652	131	403
34	CAE	LN1	AMI 381 LN1	06/23/94	632	126	361
35	CAE	LN1	AMJ 382 LN1	06/25/94	666	157	409
36	CAE	LN2	ANC 387 LN2	06/17/94	2131	1	
37	CAE	LN2	AND 388 LN2	06/18/94	2061	1	
38	CAE	LN2	ANE 389 LN2	06/20/94	2050	1	
39	CAE	LN2	ANF 390 LN2	06/20/94	2095	2	615
40	CAE	LN2	ANG 391 LN2	06/22/94	2088	1	
41	CAE	LN3	AOA 397 LN3	06/15/94	347	48	206
42	CAE	LN3	AOB 398 LN3	06/15/94	367	72	224
43	CAE	LN3	AOD 400 LN3	06/18/94	364	68	218
44	CAE	LN3	AOH 404 LN3	06/22/94	353	101	204
45	CAE	LN3	AOJ 406 LN3	06/25/94	358	66	213
46	CAE	LN4	APC 411 LN4	06/17/94	243	8	212
47	CAE	LN4	APD 412 LN4	06/18/94	259	6	240
48	CAE	LN4	APE 413 LN4	06/20/94	245	7	219
49	CAE	LN4	APH 416 LN4	06/23/94	219	4	201
50	CAE	LN4	APJ 418 LN4	06/25/94	216	15	196
51	CAE	LN5	AQC 423 LN5	06/17/94	206	347	101
52	CAE	LN5	AQE 425 LN5	06/20/94	201	279	95
53	CAE	LN5	AQG 427 LN5	06/22/94	206	260	119
54	CAE	LN5	AQH 428 LN5	06/22/94	209	156	123
55	CAE	LN5	AQJ 430 LN5	06/25/94	218	246	114
56	CAE	LN6	ARC 435 LN6	06/17/94	819	228	40
57	CAE	LN6	ARD 436 LN6	06/18/94	795	225	20
58	CAE	LN6	ARE 437 LN6	06/18/94	824	220	31
59	CAE	LN6	ARI 441 LN6	06/23/94	767	197	10
60	CAE	LN6	ARJ 442 LN6	06/25/94	819	225	37
61	CAE	RE1	BBA 553 RE1	06/25/94	885	8	746
62	CAE	RE1	BBB 554 RE1	06/25/94	812	7	698
63	CAE	RE1	BBE 557 RE1	06/25/94	878	11	537
64	CAE	RE1	BBF 558 RE1	06/25/94	845	7	735
65	CAE	RE1	BBG 559 RE1	06/25/94	857	8	443
66	CAE	RE2	BCA 565 RE2	06/25/94	4165	3	548
67	CAE	RE2	BCC 567 RE2	06/25/94	4575	3	4179
68	CAE	RE2	BCD 568 RE2	06/25/94	4139	16	3807
69	CAE	RE2	BCE 569 RE2	06/25/94	4693	3	3276
70	CAE	RE2	BCG 571 RE2	06/25/94	4249	3	2115
71	CAE	RE3	BDA 577 RE3	06/25/94	3657	2	1187
72	CAE	RE3	BDB 578 RE3	06/25/94	4463	11	4458
73	CAE	RE3	BDC 579 RE3	06/25/94	4630	5	1015
74	CAE	RE3	BDE 581 RE3	06/25/94	4446	3	3232
75	CAE	RE3	BDI 585 RE3	06/25/94	4111	3	1980
76	CAE	RN1	AYB 518 RN1	06/25/94	6037	7	5012

Viscoelasticity Results for Unexposed Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Tensile Strength (psi)	Elongation (%)	Stiffness (psi)
77	CAE	RN1	AYC 519 RN1	06/25/94	5451	9	5094
78	CAE	RN1	AYE 521 RN1	06/25/94	4763	6	4597
79	CAE	RN1	AYF 522 RN1	06/25/94	5598	10	5268
80	CAE	RN1	AYH 524 RN1	06/25/94	5431	6	5152
81	CAE	RN2	AZB 530 RN2	06/25/94	4989	8	4468
82	CAE	RN2	AZE 533 RN2	06/25/94	5177	6	4941
83	CAE	RN2	AZH 536 RN2	06/25/94	5775	6	4459
84	CAE	RN2	AZI 537 RN2	06/25/94	5733	7	5479
85	CAE	RN2	AZJ 538 RN2	06/25/94	4979	6	4847
86	CAE	RN3	BAA 541 RN3	06/25/94	7378	9	7000
87	CAE	RN3	BAB 542 RN3	06/25/94	5555	4	4555
88	CAE	RN3	BAD 544 RN3	06/25/94	1934	26	1180
89	CAE	RN3	BAG 547 RN3	06/25/94	1766	28	1133
90	CAE	RN3	BAH 548 RN3	06/25/94	1898	27	1313
91	PSI	LE1	LE1-1	08/12/94	823	18	392
92	PSI	LE1	LE1-10	08/12/94	659	14	286
93	PSI	LE1	LE1-6	08/12/94	613	14	314
94	PSI	LE1	LE1-8	08/12/94	604	16	245
95	PSI	LE1	LE1-9	08/12/94	612	11	297
96	PSI	LE2	LE2-1	08/12/94	586	33	250
97	PSI	LE2	LE2-10	08/12/94	560	36	142
98	PSI	LE2	LE2-2	08/12/94	528	45	172
99	PSI	LE2	LE2-4	08/12/94	527	40	149
100	PSI	LE2	LE2-9	08/12/94	565	39	167
101	PSI	LE3	LE3-1	08/17/94	233	275	17
102	PSI	LE3	LE3-2	08/17/94	343	480	24
103	PSI	LE3	LE3-3	08/17/94	342	292	16
104	PSI	LE3	LE3-4	08/17/94	411	281	16
105	PSI	LE3	LE3-9	08/17/94			
106	PSI	LE4	LE4-10	08/16/94	921	274	377
107	PSI	LE4	LE4-5	08/16/94	809	272	153
108	PSI	LE4	LE4-6	08/16/94	770	256	293
109	PSI	LE4	LE4-7	08/16/94	877	276	212
110	PSI	LE4	LE4-9	08/16/94	796	245	335
111	PSI	LE5	LE5-1	08/15/94	140	38	
112	PSI	LE5	LE5-2	08/15/94	284	119	
113	PSI	LE5	LE5-3	08/15/94	330	1091	
114	PSI	LE5	LE5-4	08/15/94	398	743	
115	PSI	LE5	LE5-5	08/15/94	362	890	
116	PSI	LE6	LE6-10	08/16/94	331	22	138
117	PSI	LE6	LE6-3	08/16/94	259	123	102
118	PSI	LE6	LE6-5	08/16/94	267	121	120
119	PSI	LE6	LE6-8	08/16/94	259	54	113
120	PSI	LE6	LE6-9	08/16/94	251	40	104
121	PSI	LN1	LN1-1	08/12/94	405	95	194
122	PSI	LN1	LN1-3	08/12/94	504	610	49
123	PSI	LN1	LN1-5	08/12/94	465	256	171
124	PSI	LN1	LN1-6	08/12/94	410	281	71
125	PSI	LN1	LN1-8	08/12/94	402	399	71
126	PSI	LN2	LN2-10	08/12/94	1241	2	908
127	PSI	LN2	LN2-2	08/12/94	1181	1	821
128	PSI	LN2	LN2-5	08/12/94	954	1	814
129	PSI	LN2	LN2-7	08/12/94	892	1	786
130	PSI	LN2	LN2-8	08/12/94	881	1	771
131	PSI	LN3	LN3-1	08/10/94	322	60	71
132	PSI	LN3	LN3-3	08/10/94	327	36	120
133	PSI	LN3	LN3-4	08/10/94	331	45	89
134	PSI	LN3	LN3-5	08/10/94	335	49	138
135	PSI	LN3	LN3-6	08/10/94	328	53	122
136	PSI	LN4	LN4-3	08/12/94	148	15	128
137	PSI	LN4	LN4-4	08/12/94	142	15	114
138	PSI	LN4	LN4-5	08/12/94	131	19	105
139	PSI	LN4	LN4-6	08/12/94	122	25	92
140	PSI	LN4	LN4-7	08/12/94	121	13	90
141	PSI	LN5	LN5-10	08/10/94	221	247	40
142	PSI	LN5	LN5-3	08/10/94	192	314	36
143	PSI	LN5	LN5-5	08/10/94	191	253	36
144	PSI	LN5	LN5-8	08/10/94	202	303	35
145	PSI	LN5	LN5-9	08/10/94	203	253	53
146	PSI	LN6	LN6-1	08/09/94	542	172	165
147	PSI	LN6	LN6-2	08/09/94	567	261	107
148	PSI	LN6	LN6-3	08/09/94	593	273	107
149	PSI	LN6	LN6-4	08/09/94	539	187	92
150	PSI	LN6	LN6-5	08/09/94	521	190	99
151	PSI	RE1	RE1-10	08/15/94	1844	10	659
152	PSI	RE1	RE1-2	08/15/94	1975	5	436

Viscoelasticity Results for Unexposed Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Tensile Strength (psi)	Elongation (%)	Stiffness (psi)
153	PSI	RE1	RE1-4	08/15/94	2459	17	555
154	PSI	RE1	RE1-5	08/15/94	1895	12	662
155	PSI	RE1	RE1-6	08/15/94	2187	12	641
156	PSI	RE2	RE2-1	08/15/94	3070	4	1335
157	PSI	RE2	RE2-6	08/15/94	2885	4	1240
158	PSI	RE2	RE2-7	08/15/94	4356	7	1450
159	PSI	RE2	RE2-8	08/15/94	3000	6	976
160	PSI	RE2	RE2-9	08/15/94	2912	7	1271
161	PSI	RE3	RE3-2	08/08/94	3199	2	1418
162	PSI	RE3	RE3-3	08/08/94	3345	2	1341
163	PSI	RE3	RE3-4	08/08/94	3434	1	882
164	PSI	RE3	RE3-7	08/08/94	3417	4	2220
165	PSI	RE3	RE3-8	08/08/94	3239	9	2034
166	PSI	RN1	RN1-10	08/08/94	3412	17	1207
167	PSI	RN1	RN1-2	08/08/94	3310	17	1220
168	PSI	RN1	RN1-6	08/08/94	3173	17	1211
169	PSI	RN1	RN1-7	08/08/94	3646	12	1136
170	PSI	RN1	RN1-8	08/08/94	3349	21	1000
171	PSI	RN2	RN2-10	08/08/94	2725	2	1273
172	PSI	RN2	RN2-3	08/08/94	2976	16	1216
173	PSI	RN2	RN2-5	08/08/94	3125	10	1498
174	PSI	RN2	RN2-8	08/08/94	2729	9	1267
175	PSI	RN2	RN2-9	08/08/94	3102	3	1177
176	PSI	RN3	RN3-1	08/08/94	1440	27	629
177	PSI	RN3	RN3-3	08/08/94	1442	30	617
178	PSI	RN3	RN3-6	08/08/94	1627	23	776
179	PSI	RN3	RN3-7	08/08/94	1412	25	650
180	PSI	RN3	RN3-9	08/08/94	1418	29	624

OBS	Laboratory	Product ID	Panel Number	Testing Date	Blistering Rating (0-10)
1	CAE	LE1	AGQ 173 LE1	06/14/94	10
2	CAE	LE1	AGR 174 LE1	06/14/94	10
3	CAE	LE1	AGS 175 LE1	06/22/94	10
4	CAE	LE1	AGT 176 LE1	04/28/94	10
5	CAE	LE2	AHQ 199 LE2	06/14/94	10
6	CAE	LE2	AHR 200 LE2	06/14/94	10
7	CAE	LE2	AHS 201 LE2	06/22/94	10
8	CAE	LE2	AHT 202 LE2	04/28/94	10
9	CAE	LE3	AIQ 225 LE3	06/14/94	10
10	CAE	LE3	AIR 226 LE3	06/14/94	10
11	CAE	LE3	AIS 227 LE3	06/22/94	10
12	CAE	LE3	AIT 228 LE3	04/28/94	10
13	CAE	LE4	AJQ 251 LE4	06/14/94	10
14	CAE	LE4	AJR 252 LE4	06/14/94	10
15	CAE	LE4	AJS 253 LE4	06/22/94	10
16	CAE	LE4	AJT 254 LE4	04/28/94	4F
17	CAE	LE5	AKQ 277 LE5	06/14/94	10
18	CAE	LE5	AKR 278 LE5	06/14/94	10
19	CAE	LE5	AKS 279 LE5	06/22/94	10
20	CAE	LE5	AKT 280 LE5	04/28/94	10
21	CAE	LE6	ALQ 303 LE6	06/14/94	3D
22	CAE	LE6	ALR 304 LE6	06/14/94	3D
23	CAE	LE6	ALS 305 LE6	06/22/94	2D
24	CAE	LE6	ALT 306 LE6	04/28/94	2M
25	CAE	LN1	AAQ 017 LN1	06/14/94	2F
26	CAE	LN1	AAR 018 LN1	06/14/94	2F
27	CAE	LN1	AAS 019 LN1	06/22/94	2F
28	CAE	LN1	AAT 020 LN1	04/28/94	2F
29	CAE	LN2	ABQ 043 LN2	06/14/94	10
30	CAE	LN2	ABR 044 LN2	06/14/94	10
31	CAE	LN2	ABS 045 LN2	06/22/94	10
32	CAE	LN2	ABT 046 LN2	04/28/94	10
33	CAE	LN3	ACQ 069 LN3	06/14/94	6M
34	CAE	LN3	ACR 070 LN3	06/14/94	6F
35	CAE	LN3	ACS 071 LN3	06/22/94	6F
36	CAE	LN3	ACT 072 LN3	04/28/94	6M
37	CAE	LN4	ADQ 095 LN4	06/14/94	2MD
38	CAE	LN4	ADR 096 LN4	06/14/94	2MD
39	CAE	LN4	ADS 097 LN4	06/22/94	2MD
40	CAE	LN4	ADT 098 LN4	04/28/94	0D
41	CAE	LN5	AEQ 121 LN5	06/14/94	6F
42	CAE	LN5	AER 122 LN5	06/14/94	6F
43	CAE	LN5	AES 123 LN5	06/22/94	6M
44	CAE	LN5	AET 124 LN5	04/28/94	4MD
45	CAE	LN6	AFQ 147 LN6	06/14/94	4MD
46	CAE	LN6	AFR 148 LN6	06/14/94	4MD
47	CAE	LN6	AFS 149 LN6	06/22/94	4D
48	CAE	LN6	AFT 150 LN6	04/28/94	4D
49	CAE	RE1	BHP 673 RE1	06/14/94	10
50	CAE	RE1	BHQ 674 RE1	06/14/94	10
51	CAE	RE1	BHR 675 RE1	06/22/94	10
52	CAE	RE2	BIP 696 RE2	06/14/94	10
53	CAE	RE2	BIQ 697 RE2	06/14/94	10
54	CAE	RE2	BIR 698 RE2	06/22/94	10
55	CAE	RE3	BJQ 720 RE3	06/14/94	10
56	CAE	RE3	BJR 721 RE3	06/22/94	.
57	CAE	RE3	BJT 723 RE3	06/14/94	10
58	CAE	RN1	BEP 604 RN1	06/14/94	10
59	CAE	RN1	BEQ 605 RN1	06/14/94	10
60	CAE	RN1	BER 606 RN1	06/22/94	10
61	CAE	RN2	BFP 627 RN2	06/14/94	10
62	CAE	RN2	BFQ 628 RN2	06/14/94	10
63	CAE	RN2	BFR 629 RN2	06/22/94	10
64	CAE	RN3	BGP 650 RN3	06/14/94	10
65	CAE	RN3	BGQ 651 RN3	06/14/94	10
66	CAE	RN3	BGR 652 RN3	06/22/94	10
67	PSI	LE1	LE1-14	05/24/94	2D
68	PSI	LE1	LE1-15	06/07/94	10
69	PSI	LE1	LE1-16	06/03/94	8M
70	PSI	LE1	LE1-17	06/09/94	10
71	PSI	LE2	LE2-14	06/14/94	10
72	PSI	LE2	LE2-15	06/07/94	10
73	PSI	LE2	LE2-16	06/07/94	10
74	PSI	LE2	LE2-17	05/24/94	0
75	PSI	LE3	LE3-13	06/09/94	4D
76	PSI	LE3	LE3-14	06/08/94	4D

OBS	Laboratory	Product ID	Panel Number	Testing Date	Blistering Rating (0-10)
77	PSI	LE3	LE3-16	05/25/94	4D
78	PSI	LE3	LE3-17	05/24/94	4D
79	PSI	LE4	LE4-13	06/09/94	10
80	PSI	LE4	LE4-14	06/10/94	10
81	PSI	LE4	LE4-15	05/24/94	4M
82	PSI	LE4	LE4-17	05/25/94	4M
83	PSI	LE5	LE5-14	06/14/94	6D
84	PSI	LE5	LE5-15	06/09/94	4D
85	PSI	LE5	LE5-16	05/25/94	6D
86	PSI	LE5	LE5-17	05/24/94	4D
87	PSI	LE6	LE6-14	05/25/94	4D
88	PSI	LE6	LE6-15	06/10/94	4D
89	PSI	LE6	LE6-16	06/07/94	2D
90	PSI	LE6	LE6-17	05/24/94	2D
91	PSI	LN1	LN1-11	05/24/94	2M
92	PSI	LN1	LN1-12	06/07/94	2M
93	PSI	LN1	LN1-13	06/14/94	2M
94	PSI	LN1	LN1-14	05/25/94	2F
95	PSI	LN2	LN2-11	06/10/94	10
96	PSI	LN2	LN2-12	06/08/94	8F
97	PSI	LN2	LN2-13	05/24/94	4F
98	PSI	LN2	LN2-14	06/03/94	10
99	PSI	LN3	LN3-11	05/24/94	0
100	PSI	LN3	LN3-12	06/08/94	10
101	PSI	LN3	LN3-13	06/03/94	2F
102	PSI	LN3	LN3-14	06/09/94	10
103	PSI	LN4	LN4-11	06/09/94	10
104	PSI	LN4	LN4-12	06/14/94	6F
105	PSI	LN4	LN4-14	05/24/94	2D
106	PSI	LN4	LN4-14	06/03/94	2F
107	PSI	LN5	LN5-11	05/24/94	0
108	PSI	LN5	LN5-12	05/25/94	10
109	PSI	LN5	LN5-13	06/10/94	10
110	PSI	LN5	LN5-14	06/08/94	10
111	PSI	LN6	LN6-11	05/24/94	2D
112	PSI	LN6	LN6-12	06/07/94	4M
113	PSI	LN6	LN6-13	06/08/94	4M
114	PSI	LN6	LN6-14	06/14/94	2M
115	PSI	RE1	RE1-13	05/25/94	10
116	PSI	RE1	RE1-14	06/10/94	10
117	PSI	RE1	RE1-15	06/08/94	10
118	PSI	RE2	RE2-13	06/09/94	10
119	PSI	RE2	RE2-13	06/09/94	10
120	PSI	RE2	RE2-14	05/25/94	10
121	PSI	RE3	RE3-13	06/14/94	10
122	PSI	RE3	RE3-14	06/08/94	10
123	PSI	RE3	RE3-15	05/25/94	10
124	PSI	RN1	RN1-10	06/10/94	10
125	PSI	RN1	RN1-11	06/03/94	10
126	PSI	RN1	RN1-12	06/07/94	10
127	PSI	RN2	RN2-10	06/07/94	10
128	PSI	RN2	RN2-11	06/10/94	10
129	PSI	RN2	RN2-12	06/03/94	10
130	PSI	RN3	RN3-10	06/10/94	10
131	PSI	RN3	RN3-11	06/08/94	10
132	PSI	RN3	RN3-12	06/03/94	10

OBS	Laboratory	Product ID	Panel Number	Testing Date	Blistering Rating (0-10)
1	CAE	LE1	AGA 313 LE1	05/16/94	10
2	CAE	LE1	AGB 314 LE1	05/16/94	10
3	CAE	LE1	AGC 315 LE1	05/16/94	10
4	CAE	LE1	AGD 316 LE1	05/16/94	10
5	CAE	LE1	AGE 317 LE1	05/17/94	10
6	CAE	LE1	AGF 318 LE1	05/17/94	10
7	CAE	LE1	AGG 319 LE1	05/17/94	10
8	CAE	LE1	AGH 320 LE1	05/17/94	10
9	CAE	LE1	AGI 321 LE1	05/17/94	10
10	CAE	LE1	AGK 322 LE1	05/17/94	10
11	CAE	LE2	AHA 323 LE2	05/16/94	10
12	CAE	LE2	AHB 324 LE2	05/16/94	10
13	CAE	LE2	AHC 325 LE2	05/16/94	10
14	CAE	LE2	AHD 326 LE2	05/16/94	10
15	CAE	LE2	AHE 327 LE2	05/17/94	10
16	CAE	LE2	AHF 328 LE2	05/17/94	10
17	CAE	LE2	AHG 329 LE2	05/17/94	10
18	CAE	LE2	AHH 330 LE2	05/17/94	10
19	CAE	LE2	AHI 331 LE2	05/17/94	10
20	CAE	LE2	AHK 332 LE2	05/17/94	10
21	CAE	LE3	AIA 333 LE3	05/16/94	10
22	CAE	LE3	AIB 334 LE3	05/16/94	10
23	CAE	LE3	AIC 553 LE3	05/16/94	10
24	CAE	LE3	AID 336 LE3	05/16/94	10
25	CAE	LE3	AIE 337 LE3	05/17/94	10
26	CAE	LE3	AIF 338 LE3	05/17/94	10
27	CAE	LE3	AIG 339 LE3	05/17/94	10
28	CAE	LE3	AIH 340 LE3	05/17/94	10
29	CAE	LE3	AII 341 LE3	05/17/94	10
30	CAE	LE3	AIK 342 LE3	05/17/94	10
31	CAE	LE4	AJA 343 LE4	05/16/94	10
32	CAE	LE4	AJB 344 LE4	05/16/94	10
33	CAE	LE4	AJC 345 LE4	05/16/94	10
34	CAE	LE4	AJD 346 LE4	05/16/94	10
35	CAE	LE4	AJE 347 LE4	05/17/94	10
36	CAE	LE4	AJF 348 LE4	05/17/94	10
37	CAE	LE4	AJG 349 LE4	05/17/94	10
38	CAE	LE4	AJH 350 LE4	05/17/94	10
39	CAE	LE4	AJI 351 LE4	05/17/94	10
40	CAE	LE4	AJK 352 LE4	05/17/94	10
41	CAE	LE5	AKA 353 LE5	05/16/94	10
42	CAE	LE5	AKB 354 LE5	05/16/94	10
43	CAE	LE5	AKC 355 LE5	05/16/94	10
44	CAE	LE5	AKD 356 LE5	05/16/94	10
45	CAE	LE5	AKE 357 LE5	05/17/94	10
46	CAE	LE5	AKF 358 LE5	05/17/94	10
47	CAE	LE5	AKG 359 LE5	05/17/94	10
48	CAE	LE5	AKH 360 LE5	05/17/94	10
49	CAE	LE5	AKI 361 LE5	05/17/94	10
50	CAE	LE5	AKK 362 LE5	05/17/94	10
51	CAE	LE6	ALA 363 LE6	05/16/94	10
52	CAE	LE6	ALB 364 LE6	05/16/94	10
53	CAE	LE6	ALC 365 LE6	05/16/94	10
54	CAE	LE6	ALD 366 LE6	05/16/94	10
55	CAE	LE6	ALF 368 LE6	05/17/94	10
56	CAE	LE6	ALG 369 LE6	05/17/94	10
57	CAE	LE6	ALH 370 LE6	05/17/94	10
58	CAE	LE6	ALI 371 LE6	05/17/94	10
59	CAE	LE6	ALK 372 LE6	05/17/94	10
60	CAE	LE6	ALV 308 LE6	05/17/94	10
61	CAE	RE1	BKA 728 RE1	05/16/94	10
62	CAE	RE1	BKB 729 RE1	05/16/94	10
63	CAE	RE1	BKC 730 RE1	05/16/94	10
64	CAE	RE1	BKD 731 RE1	05/17/94	10
65	CAE	RE1	BKE 732 RE1	05/17/94	10
66	CAE	RE1	BKF 733 RE1	05/17/94	10
67	CAE	RE1	BKH 735 RE1	05/17/94	10
68	CAE	RE1	BKI 736 RE1	05/17/94	10
69	CAE	RE1	BKJ 737 RE1	05/17/94	10
70	CAE	RE2	BLA 738 RE2	05/16/94	10
71	CAE	RE2	BLB 739 RE2	05/16/94	10
72	CAE	RE2	BLC 740 RE2	05/16/94	10
73	CAE	RE2	BLD 741 RE2	05/17/94	10
74	CAE	RE2	BLE 742 RE2	05/17/94	10
75	CAE	RE2	BLF 743 RE2	05/17/94	10
76	CAE	RE2	BLH 745 RE2	05/17/94	10

OBS	Laboratory	Product ID	Panel Number	Testing Date	Blistering Rating (0-10)
77	CAE	RE2	BLI 746 RE2	05/17/94	10
78	CAE	RE2	BLJ 747 RE2	05/17/94	10
79	CAE	RE3	BMA 748 RE3	05/16/94	10
80	CAE	RE3	BMB 749 RE3	05/16/94	10
81	CAE	RE3	BMC 750 RE3	05/16/94	10
82	CAE	RE3	BMD 751 RE3	05/17/94	10
83	CAE	RE3	BME 752 RE3	05/17/94	10
84	CAE	RE3	BMF 753 RE3	05/17/94	10
85	CAE	RE3	BMH 755 RE3	05/17/94	10
86	CAE	RE3	BMI 756 RE3	05/17/94	10
87	CAE	RE3	BMJ 757 RE3	05/17/94	10
88	PSI	LE1	LE1-18	05/23/94	10
89	PSI	LE1	LE1-19	05/24/94	10
90	PSI	LE1	LE1-20	05/24/94	10
91	PSI	LE1	LE1-21	06/28/94	10
92	PSI	LE1	LE1-22	06/28/94	10
93	PSI	LE1	LE1-23	06/28/94	10
94	PSI	LE1	LE1-24	07/29/94	10
95	PSI	LE1	LE1-4	06/28/94	10
96	PSI	LE1	LE1-5	06/28/94	10
97	PSI	LE1	LE1-6	06/28/94	10
98	PSI	LE2	LE2-18	05/24/94	10
99	PSI	LE2	LE2-19	05/24/94	10
100	PSI	LE2	LE2-20	05/23/94	10
101	PSI	LE2	LE2-21	06/28/94	10
102	PSI	LE2	LE2-22	06/28/94	10
103	PSI	LE2	LE2-23	06/28/94	10
104	PSI	LE2	LE2-24	07/29/94	10
105	PSI	LE2	LE2-4	06/28/94	10
106	PSI	LE2	LE2-5	06/28/94	10
107	PSI	LE2	LE2-6	06/28/94	10
108	PSI	LE3	LE3-18	05/23/94	10
109	PSI	LE3	LE3-19	05/24/94	10
110	PSI	LE3	LE3-20	05/24/94	10
111	PSI	LE3	LE3-21	06/28/94	10
112	PSI	LE3	LE3-22	06/28/94	10
113	PSI	LE3	LE3-23	06/28/94	10
114	PSI	LE3	LE3-24	07/29/94	10
115	PSI	LE3	LE3-4	06/28/94	10
116	PSI	LE3	LE3-5	07/01/94	10
117	PSI	LE3	LE3-6	06/28/94	10
118	PSI	LE4	LE4-18	05/24/94	10
119	PSI	LE4	LE4-19	05/24/94	10
120	PSI	LE4	LE4-20	05/23/94	10
121	PSI	LE4	LE4-21	06/28/94	8F
122	PSI	LE4	LE4-22	06/28/94	10
123	PSI	LE4	LE4-23	06/28/94	10
124	PSI	LE4	LE4-24	07/29/94	10
125	PSI	LE4	LE4-4	06/28/94	10
126	PSI	LE4	LE4-5	06/28/94	10
127	PSI	LE4	LE4-6	06/28/94	10
128	PSI	LE5	LE5-18	05/24/94	10
129	PSI	LE5	LE5-19	05/23/94	10
130	PSI	LE5	LE5-20	05/24/94	10
131	PSI	LE5	LE5-21	06/28/94	10
132	PSI	LE5	LE5-22	06/28/94	10
133	PSI	LE5	LE5-23	06/28/94	10
134	PSI	LE5	LE5-24	07/29/94	10
135	PSI	LE5	LE5-4	06/30/94	10
136	PSI	LE5	LE5-5	06/28/94	10
137	PSI	LE5	LE5-6	07/06/94	10
138	PSI	LE6	LE6-18	05/23/94	2F
139	PSI	LE6	LE6-19	05/24/94	2F
140	PSI	LE6	LE6-20	05/24/94	2F
141	PSI	LE6	LE6-21	06/28/94	10
142	PSI	LE6	LE6-22	06/28/94	10
143	PSI	LE6	LE6-23	06/28/94	2F
144	PSI	LE6	LE6-24	07/29/94	4F
145	PSI	LE6	LE6-4	06/28/94	3F
146	PSI	LE6	LE6-5	06/28/94	4F
147	PSI	LE6	LE6-6	06/28/94	4F
148	PSI	RE1	RE1-16	05/23/94	10
149	PSI	RE1	RE1-17	05/24/94	10
150	PSI	RE1	RE1-18	05/24/94	10
151	PSI	RE1	RE1-19	06/28/94	10
152	PSI	RE1	RE1-20	06/28/94	10

OBS	Laboratory	Product ID	Panel Number	Testing Date	Blistering Rating (0-10)
153	PSI	RE1	RE1-21	06/28/94	10
154	PSI	RE1	RE1-4	06/28/94	10
155	PSI	RE1	RE1-5	06/28/94	10
156	PSI	RE1	RE1-6	07/05/94	10
157	PSI	RE2	RE2-16	05/24/94	10
158	PSI	RE2	RE2-17	05/24/94	10
159	PSI	RE2	RE2-18	05/23/94	10
160	PSI	RE2	RE2-19	06/28/94	10
161	PSI	RE2	RE2-20	06/28/94	10
162	PSI	RE2	RE2-21	06/28/94	10
163	PSI	RE2	RE2-4	06/30/94	10
164	PSI	RE2	RE2-5	07/05/94	10
165	PSI	RE2	RE2-6	07/06/94	10
166	PSI	RE3	RE3-16	05/24/94	10
167	PSI	RE3	RE3-17	05/24/94	10
168	PSI	RE3	RE3-18	05/23/94	10
169	PSI	RE3	RE3-19	06/28/94	10
170	PSI	RE3	RE3-20	06/28/94	10
171	PSI	RE3	RE3-21	06/28/94	10
172	PSI	RE3	RE3-4	07/01/94	10
173	PSI	RE3	RE3-5	07/05/94	10
174	PSI	RE3	RE3-6	06/28/94	10

OBS	Laboratory	Product ID	Panel Number	Testing Date	Chalking Rating (0-10)
1	CAE	LE1	AGA 313 LE1	06/08/94	7.0
2	CAE	LE1	AGB 314 LE1	05/16/94	8.0
3	CAE	LE1	AGC 315 LE1	05/16/94	7.0
4	CAE	LE1	AGD 316 LE1	05/16/94	6.0
5	CAE	LE1	AGE 317 LE1	05/17/94	7.0
6	CAE	LE1	AGF 318 LE1	05/17/94	6.0
7	CAE	LE1	AGG 319 LE1	05/17/94	7.0
8	CAE	LE1	AGH 320 LE1	05/17/94	7.0
9	CAE	LE1	AGI 321 LE1	05/17/94	7.0
10	CAE	LE1	AGK 322 LE1	05/17/94	7.0
11	CAE	LE2	AHA 323 LE2	06/08/94	7.0
12	CAE	LE2	AHB 324 LE2	05/16/94	7.0
13	CAE	LE2	AHC 325 LE2	05/16/94	7.0
14	CAE	LE2	AHD 326 LE2	05/16/94	6.0
15	CAE	LE2	AHE 327 LE2	05/17/94	7.0
16	CAE	LE2	AHF 328 LE2	05/17/94	7.0
17	CAE	LE2	AHG 329 LE2	05/17/94	7.0
18	CAE	LE2	AHH 330 LE2	05/17/94	7.0
19	CAE	LE2	AHI 331 LE2	05/17/94	7.0
20	CAE	LE2	AHK 332 LE2	05/17/94	7.0
21	CAE	LE3	AIA 333 LE3	06/08/94	8.0
22	CAE	LE3	AIB 334 LE3	05/16/94	9.0
23	CAE	LE3	AIC 553 LE3	05/16/94	9.0
24	CAE	LE3	AID 336 LE3	05/16/94	9.0
25	CAE	LE3	AIE 337 LE3	05/17/94	10.0
26	CAE	LE3	AIF 338 LE3	05/17/94	9.0
27	CAE	LE3	AIG 339 LE3	05/17/94	9.0
28	CAE	LE3	AIH 340 LE3	05/17/94	9.0
29	CAE	LE3	AII 341 LE3	05/17/94	9.0
30	CAE	LE3	AIK 342 LE3	05/17/94	9.0
31	CAE	LE4	AJA 343 LE4	06/08/94	9.0
32	CAE	LE4	AJB 344 LE4	05/16/94	10.0
33	CAE	LE4	AJC 345 LE4	05/16/94	10.0
34	CAE	LE4	AJD 346 LE4	05/16/94	9.0
35	CAE	LE4	AJE 347 LE4	05/17/94	10.0
36	CAE	LE4	AJF 348 LE4	05/17/94	9.0
37	CAE	LE4	AJG 349 LE4	05/17/94	9.0
38	CAE	LE4	AJH 350 LE4	05/17/94	10.0
39	CAE	LE4	AJI 351 LE4	05/17/94	10.0
40	CAE	LE4	AJK 352 LE4	05/17/94	.
41	CAE	LE5	AKA 353 LE5	06/08/94	8.0
42	CAE	LE5	AKB 354 LE5	05/16/94	8.0
43	CAE	LE5	AKC 355 LE5	05/16/94	9.0
44	CAE	LE5	AKD 356 LE5	05/16/94	9.0
45	CAE	LE5	AKE 357 LE5	05/17/94	10.0
46	CAE	LE5	AKF 358 LE5	05/17/94	9.0
47	CAE	LE5	AKG 359 LE5	05/17/94	9.0
48	CAE	LE5	AKH 360 LE5	05/17/94	9.0
49	CAE	LE5	AKI 361 LE5	05/17/94	9.0
50	CAE	LE5	AKK 362 LE5	05/17/94	10.0
51	CAE	LE6	ALA 363 LE6	06/08/94	7.0
52	CAE	LE6	ALB 364 LE6	05/16/94	8.0
53	CAE	LE6	ALC 365 LE6	05/16/94	8.0
54	CAE	LE6	ALD 366 LE6	05/16/94	8.0
55	CAE	LE6	ALF 368 LE6	05/17/94	6.0
56	CAE	LE6	ALG 369 LE6	05/17/94	8.0
57	CAE	LE6	ALH 370 LE6	05/17/94	8.0
58	CAE	LE6	ALI 371 LE6	05/17/94	8.0
59	CAE	LE6	ALK 372 LE6	05/17/94	8.0
60	CAE	LE6	ALV 308 LE6	05/17/94	8.0
61	CAE	RE1	BKA 728 RE1	05/16/94	10.0
62	CAE	RE1	BKB 729 RE1	05/16/94	10.0
63	CAE	RE1	BKC 730 RE1	05/16/94	10.0
64	CAE	RE1	BKD 731 RE1	05/17/94	10.0
65	CAE	RE1	BKE 732 RE1	05/17/94	10.0
66	CAE	RE1	BKF 733 RE1	05/17/94	10.0
67	CAE	RE1	BKH 735 RE1	05/17/94	10.0
68	CAE	RE1	BKI 736 RE1	05/17/94	9.0
69	CAE	RE1	BKJ 737 RE1	05/17/94	9.0
70	CAE	RE2	BLA 738 RE2	05/16/94	7.0
71	CAE	RE2	BLB 739 RE2	05/16/94	7.0
72	CAE	RE2	BLC 740 RE2	05/16/94	6.0
73	CAE	RE2	BLD 741 RE2	05/17/94	7.0
74	CAE	RE2	BLE 742 RE2	05/17/94	6.0
75	CAE	RE2	BLF 743 RE2	05/17/94	7.0
76	CAE	RE2	BLH 745 RE2	05/17/94	8.0

OBS	Laboratory	Product ID	Panel Number	Testing Date	Chalking Rating (0-10)
77	CAE	RE2	BLI 746 RE2	05/17/94	8.0
78	CAE	RE2	BLJ 747 RE2	05/17/94	7.0
79	CAE	RE3	BMA 748 RE3	05/16/94	7.0
80	CAE	RE3	BMB 749 RE3	05/16/94	7.0
81	CAE	RE3	BMC 750 RE3	05/16/94	7.0
82	CAE	RE3	BMD 751 RE3	05/17/94	7.0
83	CAE	RE3	BME 752 RE3	05/17/94	7.0
84	CAE	RE3	BMF 753 RE3	05/17/94	7.0
85	CAE	RE3	BMH 755 RE3	05/17/94	8.0
86	CAE	RE3	BMI 756 RE3	05/17/94	7.0
87	CAE	RE3	BMJ 757 RE3	05/17/94	7.0
88	PSI	LE1	LE1-18	05/23/94	7.5
89	PSI	LE1	LE1-19	05/24/94	7.5
90	PSI	LE1	LE1-20	05/24/94	7.5
91	PSI	LE1	LE1-21	07/26/94	7.5
92	PSI	LE1	LE1-22	07/26/94	7.5
93	PSI	LE1	LE1-23	07/26/94	7.5
94	PSI	LE1	LE1-24	07/29/94	7.5
95	PSI	LE1	LE1-4	06/28/94	7.5
96	PSI	LE1	LE1-5	06/28/94	7.0
97	PSI	LE1	LE1-6	06/28/94	7.5
98	PSI	LE2	LE2-18	05/24/94	7.5
99	PSI	LE2	LE2-19	05/24/94	7.5
100	PSI	LE2	LE2-20	05/23/94	7.5
101	PSI	LE2	LE2-21	07/26/94	7.5
102	PSI	LE2	LE2-22	07/26/94	7.5
103	PSI	LE2	LE2-23	07/26/94	7.5
104	PSI	LE2	LE2-24	07/29/94	7.0
105	PSI	LE2	LE2-4	06/28/94	7.5
106	PSI	LE2	LE2-5	06/28/94	7.5
107	PSI	LE2	LE2-6	06/28/94	8.0
108	PSI	LE3	LE3-18	05/23/94	8.0
109	PSI	LE3	LE3-19	05/24/94	8.0
110	PSI	LE3	LE3-20	05/24/94	8.0
111	PSI	LE3	LE3-21	07/26/94	8.0
112	PSI	LE3	LE3-22	07/26/94	8.0
113	PSI	LE3	LE3-23	07/26/94	8.0
114	PSI	LE3	LE3-24	07/29/94	8.0
115	PSI	LE3	LE3-4	06/28/94	8.0
116	PSI	LE3	LE3-5	07/01/94	8.0
117	PSI	LE3	LE3-6	06/28/94	8.0
118	PSI	LE4	LE4-18	05/24/94	8.0
119	PSI	LE4	LE4-19	05/24/94	8.0
120	PSI	LE4	LE4-20	05/23/94	8.0
121	PSI	LE4	LE4-21	07/26/94	8.0
122	PSI	LE4	LE4-22	07/26/94	8.0
123	PSI	LE4	LE4-23	07/26/94	8.0
124	PSI	LE4	LE4-24	07/29/94	8.0
125	PSI	LE4	LE4-4	06/28/94	8.0
126	PSI	LE4	LE4-5	06/28/94	8.0
127	PSI	LE4	LE4-6	06/28/94	8.0
128	PSI	LE5	LE5-18	05/24/94	8.0
129	PSI	LE5	LE5-19	05/23/94	8.0
130	PSI	LE5	LE5-20	05/24/94	8.0
131	PSI	LE5	LE5-21	07/26/94	8.0
132	PSI	LE5	LE5-22	07/26/94	8.0
133	PSI	LE5	LE5-23	07/26/94	8.0
134	PSI	LE5	LE5-24	07/29/94	8.0
135	PSI	LE5	LE5-4	06/30/94	8.0
136	PSI	LE5	LE5-5	06/28/94	8.0
137	PSI	LE5	LE5-6	07/06/94	8.0
138	PSI	LE6	LE6-18	05/23/94	7.5
139	PSI	LE6	LE6-19	05/24/94	7.5
140	PSI	LE6	LE6-20	05/24/94	7.5
141	PSI	LE6	LE6-21	07/26/94	7.5
142	PSI	LE6	LE6-22	07/26/94	7.5
143	PSI	LE6	LE6-23	07/26/94	7.5
144	PSI	LE6	LE6-24	07/29/94	7.5
145	PSI	LE6	LE6-4	06/28/94	7.0
146	PSI	LE6	LE6-5	06/28/94	7.5
147	PSI	LE6	LE6-6	06/28/94	7.5
148	PSI	RE1	RE1-16	05/23/94	8.0
149	PSI	RE1	RE1-17	05/24/94	8.0
150	PSI	RE1	RE1-18	05/24/94	8.0
151	PSI	RE1	RE1-19	07/26/94	8.0
152	PSI	RE1	RE1-20	07/26/94	8.0

Chalking Results for Weathered Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Chalking Rating (0-10)
153	PSI	RE1	RE1-21	07/26/94	8.0
154	PSI	RE1	RE1-4	06/28/94	8.0
155	PSI	RE1	RE1-5	06/28/94	8.0
156	PSI	RE1	RE1-6	07/05/94	8.0
157	PSI	RE2	RE2-16	05/24/94	7.0
158	PSI	RE2	RE2-17	05/24/94	7.0
159	PSI	RE2	RE2-18	05/23/94	7.0
160	PSI	RE2	RE2-19	07/26/94	7.0
161	PSI	RE2	RE2-20	07/26/94	6.5
162	PSI	RE2	RE2-21	07/26/94	7.0
163	PSI	RE2	RE2-4	06/30/94	8.0
164	PSI	RE2	RE2-5	07/05/94	8.0
165	PSI	RE2	RE2-6	07/06/94	8.0
166	PSI	RE3	RE3-16	05/24/94	7.0
167	PSI	RE3	RE3-17	05/24/94	7.0
168	PSI	RE3	RE3-18	05/23/94	7.0
169	PSI	RE3	RE3-19	07/26/94	7.0
170	PSI	RE3	RE3-20	07/26/94	7.0
171	PSI	RE3	RE3-21	07/26/94	7.0
172	PSI	RE3	RE3-4	07/01/94	8.0
173	PSI	RE3	RE3-5	07/05/94	8.0
174	PSI	RE3	RE3-6	06/28/94	7.0

OBS	Laboratory	Product ID	Panel Number	Testing Date	Gouge Rating (6B-6H)	Recoded Rating (0-13)
1	CAE	LE1	AGQ 173 LE1	04/27/94	F	7
2	CAE	LE1	AGR 174 LE1	04/29/94	HB	6
3	CAE	LE1	AGS 175 LE1	04/29/94	HB	6
4	CAE	LE1	AGU 177 LE1	05/02/94	HB	6
5	CAE	LE2	AHQ 199 LE2	04/27/94	HB	6
6	CAE	LE2	AHR 200 LE2	04/29/94	HB	6
7	CAE	LE2	AHS 201 LE2	04/29/94	HB	6
8	CAE	LE2	AHU 203 LE2	05/02/94	HB	6
9	CAE	LE3	AIQ 225 LE3	04/27/94	F	7
10	CAE	LE3	AIR 226 LE3	04/29/94	HB	6
11	CAE	LE3	AIS 227 LE3	04/29/94	HB	6
12	CAE	LE3	AIU 229 LE3	05/02/94	HB	6
13	CAE	LE4	AJQ 251 LE4	04/27/94	HB	6
14	CAE	LE4	AJR 252 LE4	04/29/94	HB	6
15	CAE	LE4	AJS 253 LE4	04/29/94	HB	6
16	CAE	LE4	AJU 255 LE4	05/02/94	B	5
17	CAE	LE5	AKQ 277 LE5	04/27/94	HB	6
18	CAE	LE5	AKR 278 LE5	04/29/94	HB	6
19	CAE	LE5	AKS 279 LE5	04/29/94	B	5
20	CAE	LE5	AKU 281 LE5	05/02/94	B	5
21	CAE	LE6	ALQ 303 LE6	04/27/94	HB	6
22	CAE	LE6	ALR 304 LE6	04/29/94	HB	6
23	CAE	LE6	ALS 305 LE6	04/29/94	B	5
24	CAE	LE6	ALU 307 LE6	05/02/94	B	5
25	CAE	LN1	AAQ 017 LN1	04/27/94	HB	6
26	CAE	LN1	AAR 018 LN1	04/29/94	HB	6
27	CAE	LN1	AAS 019 LN1	04/29/94	B	5
28	CAE	LN1	AAU 021 LN1	05/02/94	B	5
29	CAE	LN2	ABQ 043 LN2	04/27/94	F	7
30	CAE	LN2	ABR 044 LN2	04/29/94	HB	6
31	CAE	LN2	ABS 045 LN2	04/29/94	HB	6
32	CAE	LN2	ABU 047 LN2	05/02/94	HB	6
33	CAE	LN3	ACQ 069 LN3	04/27/94	F	7
34	CAE	LN3	ACR 070 LN3	04/29/94	HB	6
35	CAE	LN3	ACS 071 LN3	04/29/94	HB	6
36	CAE	LN3	ACU 073 LN3	05/02/94	HB	6
37	CAE	LN4	ADQ 095 LN4	04/27/94	F	7
38	CAE	LN4	ADR 096 LN4	04/29/94	HB	6
39	CAE	LN4	ADS 097 LN4	04/29/94	HB	6
40	CAE	LN4	ADU 099 LN4	05/02/94	HB	6
41	CAE	LN5	AEQ 121 LN5	04/27/94	HB	6
42	CAE	LN5	AER 122 LN5	04/29/94	HB	6
43	CAE	LN5	AES 123 LN5	04/29/94	HB	6
44	CAE	LN5	AEU 125 LN5	05/02/94	HB	6
45	CAE	LN6	AFQ 147 LN6	04/27/94	F	7
46	CAE	LN6	AFR 148 LN6	04/29/94	HB	6
47	CAE	LN6	AFS 149 LN6	04/29/94	HB	6
48	CAE	LN6	AFX 154 LN6	05/02/94	HB	6
49	CAE	RE1	BHP 673 RE1	04/27/94	>6H	13
50	CAE	RE1	BHQ 674 RE1	04/29/94	>6H	13
51	CAE	RE1	BHR 675 RE1	04/29/94	>6H	13
52	CAE	RE1	BHS 676 RE1	05/02/94	>6H	13
53	CAE	RE2	BIP 696 RE2	04/27/94	>6H	13
54	CAE	RE2	BIQ 697 RE2	04/29/94	>6H	13
55	CAE	RE2	BIR 698 RE2	04/29/94	>6H	13
56	CAE	RE2	BIS 699 RE2	05/02/94	>6H	13
57	CAE	RE3	BJQ 720 RE3	04/29/94	>6H	13
58	CAE	RE3	BJR 721 RE3	04/29/94	-	.
59	CAE	RE3	BJS 722 RE3	05/02/94	>6H	13
60	CAE	RE3	BJT 723 RE3	04/27/94	>6H	13
61	CAE	RN1	BEP 604 RN1	04/27/94	HB	6
62	CAE	RN1	BEQ 605 RN1	04/29/94	B	5
63	CAE	RN1	BER 606 RN1	04/29/94	B	5
64	CAE	RN1	BES 607 RN1	05/02/94	B	5
65	CAE	RN2	BFP 627 RN2	04/27/94	2B	4
66	CAE	RN2	BFQ 628 RN2	04/29/94	2B	4
67	CAE	RN2	BFR 629 RN2	04/29/94	2B	4
68	CAE	RN2	BFS 630 RN2	05/02/94	2B	4
69	CAE	RN3	BGP 650 RN3	04/27/94	F	7
70	CAE	RN3	BGQ 651 RN3	04/29/94	HB	6
71	CAE	RN3	BGR 652 RN3	04/29/94	HB	6
72	CAE	RN3	BGS 653 RN3	05/02/94	F	7
73	PSI	LE1	LE1-10	08/24/94	4B	2
74	PSI	LE2	LE2-11	08/24/94	2B	4
75	PSI	LE3	LE3-12	08/24/94	B	5
76	PSI	LE4	LE4-11	08/24/94	2B	4

OBS	Laboratory	Product ID	Panel Number	Testing Date	Gouge Rating (6B-6H)	Recoded Rating (0-13)
77	PSI	LE5	LE5-10	08/24/94	3B	3
78	PSI	LE6	LE6-11	08/24/94	3B	3
79	PSI	LN1	LN1-8	08/24/94	HB	6
80	PSI	LN2	LN2-8	08/24/94	F	7
81	PSI	LN3	LN3-7	08/24/94	B	5
82	PSI	LN4	LN4-9	08/24/94	4B	2
83	PSI	LN5	LN5-9	08/24/94	B	5
84	PSI	LN6	LN6-7	08/24/94	HB	6
85	PSI	RE1	RE1-11	08/24/94	>6H	13
86	PSI	RE2	RE2-11	08/24/94	>6H	13
87	PSI	RE3	RE3-11	08/24/94	>6H	13
88	PSI	RN1	RN1-8	08/24/94	H	8
89	PSI	RN2	RN2-8	08/24/94	H	8
90	PSI	RN3	RN3-7	08/24/94	HB	6

Pencil Hardness Results for Immersed (10 minute dry) Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Gouge Rating (6B-6H)	Recoded Rating (0-13)
1	CAE	LE1	AGQ 173 LE1	06/14/94	<6B	0
2	CAE	LE1	AGR 174 LE1	06/14/94	<6B	0
3	CAE	LE1	AGT 176 LE1	04/28/94	6B	0
4	CAE	LE2	AHQ 199 LE2	06/14/94	<6B	0
5	CAE	LE2	AHR 200 LE2	06/14/94	<6B	0
6	CAE	LE2	AHT 202 LE2	04/28/94	<6B	0
7	CAE	LE3	AIQ 225 LE3	06/14/94	<6B	0
8	CAE	LE3	AIR 226 LE3	06/14/94	<6B	0
9	CAE	LE3	AIT 228 LE3	04/28/94	<6B	0
10	CAE	LE4	AJQ 251 LE4	06/14/94	6B	0
11	CAE	LE4	AJR 252 LE4	06/14/94	6B	0
12	CAE	LE4	AJT 254 LE4	04/28/94	6B	0
13	CAE	LE5	AKQ 277 LE5	06/14/94	<6B	0
14	CAE	LE5	AKR 278 LE5	06/14/94	<6B	0
15	CAE	LE5	AKT 280 LE5	04/28/94	<6B	0
16	CAE	LE6	ALQ 303 LE6	06/14/94	<6B	0
17	CAE	LE6	ALR 304 LE6	06/14/94	<6B	0
18	CAE	LE6	ALT 306 LE6	04/28/94	<6B	0
19	CAE	LN1	AAQ 017 LN1	06/14/94	<6B	0
20	CAE	LN1	AAR 018 LN1	06/14/94	<6B	0
21	CAE	LN1	AAT 020 LN1	04/28/94	<6B	0
22	CAE	LN2	ABQ 043 LN2	06/14/94	<6B	0
23	CAE	LN2	ABR 044 LN2	06/14/94	<6B	0
24	CAE	LN2	ABT 046 LN2	04/28/94	<6B	0
25	CAE	LN3	ACQ 069 LN3	06/14/94	<6B	0
26	CAE	LN3	ACR 070 LN3	06/14/94	<6B	0
27	CAE	LN3	ACT 072 LN3	04/28/94	<6B	0
28	CAE	LN4	ADQ 095 LN4	06/14/94	<6B	0
29	CAE	LN4	ADR 096 LN4	06/14/94	<6B	0
30	CAE	LN4	ADT 098 LN4	04/28/94	<6B	0
31	CAE	LN5	AEQ 121 LN5	06/14/94	<6B	0
32	CAE	LN5	AER 122 LN5	06/14/94	<6B	0
33	CAE	LN5	AET 124 LN5	04/28/94	<6B	0
34	CAE	LN6	AFQ 147 LN6	06/14/94	<6B	0
35	CAE	LN6	AFR 148 LN6	06/14/94	<6B	0
36	CAE	LN6	AFT 150 LN6	04/28/94	6B	0
37	CAE	RE1	BHP 673 RE1	06/14/94	>6H	13
38	CAE	RE1	BHQ 674 RE1	06/14/94	>6H	13
39	CAE	RE2	BIP 696 RE2	06/14/94	>6H	13
40	CAE	RE2	BIQ 697 RE2	06/14/94	>6H	13
41	CAE	RE3	BJQ 720 RE3	06/14/94	>6H	13
42	CAE	RE3	BJT 723 RE3	06/14/94	>6H	13
43	CAE	RN1	BEP 604 RN1	06/14/94	<6B	0
44	CAE	RN1	BEQ 605 RN1	06/14/94	<6B	0
45	CAE	RN2	BFP 627 RN2	06/14/94	<6B	0
46	CAE	RN2	BFQ 628 RN2	06/14/94	<6B	0
47	CAE	RN3	BGP 650 RN3	06/14/94	2B	4
48	CAE	RN3	BGQ 651 RN3	06/14/94	B	5
49	PSI	LE1	LE1-14	05/24/94	<6B	0
50	PSI	LE1	LE1-15	06/07/94	<6B	0
51	PSI	LE1	LE1-16	06/03/94	<6B	0
52	PSI	LE2	LE2-15	06/07/94	4B	2
53	PSI	LE2	LE2-16	06/07/94	3B	3
54	PSI	LE2	LE2-17	05/24/94	4B	2
55	PSI	LE3	LE3-14	06/08/94	<6B	0
56	PSI	LE3	LE3-16	05/25/94	<6B	0
57	PSI	LE3	LE3-17	05/24/94	<6B	0
58	PSI	LE4	LE4-14	06/09/94	4B	2
59	PSI	LE4	LE4-15	05/24/94	5B	1
60	PSI	LE4	LE4-17	05/25/94	2H	9
61	PSI	LE5	LE5-15	06/09/94	<6B	0
62	PSI	LE5	LE5-16	05/25/94	3B	3
63	PSI	LE5	LE5-17	05/24/94	<6B	0
64	PSI	LE6	LE6-14	05/25/94	<6B	0
65	PSI	LE6	LE6-16	06/07/94	<6B	0
66	PSI	LE6	LE6-17	05/24/94	<6B	0
67	PSI	LN1	LN1-11	05/24/94	<6B	0
68	PSI	LN1	LN1-12	06/07/94	<6B	0
69	PSI	LN1	LN1-14	05/25/94	<6B	0
70	PSI	LN2	LN2-12	06/08/94	<6B	0
71	PSI	LN2	LN2-13	05/24/94	<6B	0
72	PSI	LN2	LN2-14	06/03/94	3B	3
73	PSI	LN3	LN3-11	05/24/94	<6B	0
74	PSI	LN3	LN3-12	06/08/94	<6B	0
75	PSI	LN3	LN3-13	06/03/94	5B	1
76	PSI	LN4	LN4-11	06/09/94	<6B	0

Pencil Hardness Results for Immersed (10 minute dry) Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Gouge Rating (6B-6H)	Recoded Rating (0-13)
77	PSI	LN4	LN4-14	05/24/94	5B	1
78	PSI	LN4	LN4-14	06/03/94	6B	0
79	PSI	LN5	LN5-11	05/24/94	<6B	0
80	PSI	LN5	LN5-12	05/25/94	<6B	0
81	PSI	LN5	LN5-14	06/08/94	<6B	0
82	PSI	LN6	LN6-11	05/24/94	<6B	0
83	PSI	LN6	LN6-12	06/07/94	6B	0
84	PSI	LN6	LN6-13	06/08/94	6B	0
85	PSI	RE1	RE1-13	05/25/94	>6H	13
86	PSI	RE1	RE1-15	06/08/94	>6H	13
87	PSI	RE2	RE2-14	05/25/94	>6H	13
88	PSI	RE2	RE2-15	06/09/94	>6H	13
89	PSI	RE3	RE3-14	06/08/94	>6H	13
90	PSI	RE3	RE3-15	05/25/94	>6H	13
91	PSI	RN1	RN1-11	06/03/94	<6B	0
92	PSI	RN1	RN1-12	06/07/94	<6B	0
93	PSI	RN2	RN2-10	06/07/94	<6B	0
94	PSI	RN2	RN2-12	06/03/94	<6B	0
95	PSI	RN3	RN3-11	06/08/94	B	5
96	PSI	RN3	RN3-12	06/03/94	5H	12

Pencil Hardness Results for Immersed (120 minute dry) Panels

OBS	Laboratory	Product ID	Panel Number	Testing Date	Gouge Rating (6B-6H)	Recoded Rating (0-13)
1	CAE	LE1	AGS 175 LE1	06/22/94	3B	3
2	CAE	LE1	AGT 176 LE1	04/28/94	4B	2
3	CAE	LE2	AHS 201 LE2	06/22/94	HB	6
4	CAE	LE2	AHT 202 LE2	04/28/94	2B	4
5	CAE	LE3	AIS 227 LE3	06/22/94	6B	0
6	CAE	LE3	AIT 228 LE3	04/28/94	4B	2
7	CAE	LE4	AJS 253 LE4	06/22/94	4B	2
8	CAE	LE4	AJT 254 LE4	04/28/94	4B	2
9	CAE	LE5	AKS 279 LE5	06/22/94	3B	3
10	CAE	LE5	AKT 280 LE5	04/28/94	2B	4
11	CAE	LE6	ALS 305 LE6	06/22/94	<6B	0
12	CAE	LE6	ALT 306 LE6	04/28/94	2B	4
13	CAE	LN1	AAS 019 LN1	06/22/94	<6B	0
14	CAE	LN1	AAT 020 LN1	04/28/94	2B	4
15	CAE	LN2	ABS 045 LN2	06/22/94	3B	3
16	CAE	LN2	ABT 046 LN2	04/28/94	4B	2
17	CAE	LN3	ACS 071 LN3	06/22/94	<6B	0
18	CAE	LN3	ACT 072 LN3	04/28/94	4B	2
19	CAE	LN4	ADS 097 LN4	06/22/94	<6B	0
20	CAE	LN4	ADT 098 LN4	04/28/94		.
21	CAE	LN5	AES 123 LN5	06/22/94	<6B	0
22	CAE	LN5	AET 124 LN5	04/28/94	<6B	0
23	CAE	LN6	AFS 149 LN6	06/22/94	<6B	0
24	CAE	LN6	AFT 150 LN6	04/28/94	2B	4
25	CAE	RE1	BHR 675 RE1	06/22/94	>6H	13
26	CAE	RE2	BIR 698 RE2	06/22/94	>6H	13
27	CAE	RE3	BJR 721 RE3	06/22/94		.
28	CAE	RN1	BER 606 RN1	06/22/94	<6B	0
29	CAE	RN2	BFR 629 RN2	06/22/94	<6B	0
30	CAE	RN3	BGR 652 RN3	06/22/94	HB	6
31	PSI	LE1	LE1-14	05/24/94	<6B	0
32	PSI	LE1	LE1-17	06/09/94	<6B	0
33	PSI	LE2	LE2-14	06/14/94	B	5
34	PSI	LE2	LE2-17	05/24/94	2B	4
35	PSI	LE3	LE3-13	06/09/94	<6B	0
36	PSI	LE3	LE3-17	05/24/94	<6B	0
37	PSI	LE4	LE4-14	06/10/94	>6H	13
38	PSI	LE4	LE4-15	05/24/94	5B	1
39	PSI	LE5	LE5-14	06/14/94	<6B	0
40	PSI	LE5	LE5-17	05/24/94	<6B	0
41	PSI	LE6	LE6-15	06/10/94	<6B	0
42	PSI	LE6	LE6-17	05/24/94	4B	2
43	PSI	LN1	LN1-11	05/24/94	3B	3
44	PSI	LN1	LN1-13	06/14/94	6B	0
45	PSI	LN2	LN2-11	06/10/94	3B	3
46	PSI	LN2	LN2-13	05/24/94	<6B	0
47	PSI	LN3	LN3-11	05/24/94	<6B	0
48	PSI	LN3	LN3-14	06/09/94	6B	0
49	PSI	LN4	LN4-12	06/14/94	<6B	0
50	PSI	LN4	LN4-14	05/24/94	4B	2
51	PSI	LN5	LN5-11	05/24/94	<6B	0
52	PSI	LN5	LN5-13	06/10/94	5B	1
53	PSI	LN6	LN6-11	05/24/94	<6B	0
54	PSI	LN6	LN6-14	06/14/94	<6B	0
55	PSI	RE1	RE1-14	06/10/94	>6H	13
56	PSI	RE2	RE2-13	06/09/94	>6H	13
57	PSI	RE3	RE3-13	06/14/94	>6H	13
58	PSI	RN1	RN1-10	06/10/94	<6B	0
59	PSI	RN2	RN2-11	06/10/94	5B	1
60	PSI	RN3	RN3-10	06/10/94	5B	1